THE

POPULAR SCIENCE MONTHLY.

OCTOBER, 1880.

FASHION IN DEFORMITY.*

By WILLIAM HENRY FLOWER, LL.D., F.R.S.,

HUNTERIAN PROFESSOR OF COMPARATIVE ANATOMY, ROYAL COLLEGE OF SURGEONS OF ENGLAND.

I HAVE to ask your attention this evening to certain outward manifestations of a propensity common to human nature in every aspect in which we are acquainted with it—the most primitive and barbarous, and the most civilized and refined—but one which is, as far as I know, peculiar to human nature.

I shall speak of *deformity* in the sense of alteration of the natural form of any part of the body, and those cases of voluntary deformation will be considered which are performed, not by isolated individuals, or with special motives, but by considerable numbers of members of a community in imitation of one another—in fact, according to *fashion*, "that most inexorable tyrant, to which the greater part of mankind are willing slaves."

Fashion is now often associated with change, but in more primitive communities fashions of all sorts are more permanent than with us; and in all communities such fashions as those I am now speaking of are, for obvious reasons, far less likely to be subject to the fluctuations of caprice than those affecting the dress only, which, even in Shakespeare's time, changed so often that "the fashion wears out more apparel than the man." Alterations once made in the form of the body can not be discarded or modified in the lifetime of the individual, and therefore, as fashion is intrinsically imitative, such alterations have the strongest possible tendency to be reproduced generation after generation.

The origins of these fashions are mostly lost in obscurity, all

* A discourse delivered at the Royal Institution, Friday, May 7, 1880.

attempts to solve them being little more than guesses. Some of them have become associated with religious or superstitious observances, and so have been spread and perpetuated; some have been vaguely thought to be hygienic in motive; most have some relation to conventional standards of improved personal appearance; but, whatever their origin, the desire to conform to common usage, and not to appear singular, is the prevailing motive which leads to their continuance.

The most convenient classification of these customs will be one which is based upon the part of the body affected by them, and I will begin with the more superficial and comparatively trivial—the treatment of the hair and other appendages of the skin.

FIG 1.—AUSTRALIAN NATIVE, WITH BONE NOSE-ORNAMENT.

Here we are at once introduced to the domain of Fashion in her most potent sway. The facility with which hair lends itself to various methods of treatment has been a temptation too great to resist in all known conditions of civilization. Innumerable variations of custom exist in different parts of the world, and marked changes in at least all more or less civilized communities have characterized successive epochs of history. Not only the length and method of arrangement, but even the color of the hair, is changed in obedience to caprices of fashion. In many of the islands of the Western Pacific, the naturally jet-black hair of the natives is converted into a tawny brown by the application of lime, obtained by burning the coral found so abundantly on their shores; and, not many years since, similar means were employed for producing the same result among the ladies of Western Europe—a fact which considerably diminishes the value of an idea

entertained by many ethnologists, that community of custom is evidence of community of origin or of race.

Notwithstanding the painful and laborious nature of the process, when conducted with no better implements than flint knives, or pieces of splintered bone or shell, the custom of keeping the head closely shaved prevails extensively among savage nations. This, doubtless, tends to cleanliness, and perhaps comfort, in hot countries; but the fact that it is in many tribes practiced only by the women and children shows that these considerations are not those primarily engaged in its perpetuation. In some cases, as among the Feejeeans, while the heads of the women are commonly cropped or closely shaved, the men cultivate, at great expense of time and attention, a luxuriant and elaborately arranged mass of hair, exactly reversing the conditions met with in the most highly civilized nations.

In some regions of Africa it is considered necessary to female beauty carefully to eradicate the eyebrows, special pincers for the purpose forming part of the appliances of the toilet; while the various methods of shaving and cutting the beard among men of all nations are too well known to require more than a passing notice. The treatment of finger-nails, both as to color and form, has also been subject to fashion; but the practical inconveniences attending the inordinate length to which these are permitted to grow in some parts of the east of Asia appear to have restricted the custom to a few localities.

If time allowed, the exceedingly widespread custom of tattooing the skin might be here considered, as a result of the same propensity as that which produces the other more serious deformations, now to be spoken of; but it will be as well to pass at once to these.

The nose, the lips, and the ears have, in almost all races, offered great temptations to be used as foundations for the display of ornament, some process of boring, cutting, or alteration of form being necessary to render them fit for the purpose. When Captain Cook, exactly one hundred years ago, was describing the naked savages of the east coast of Australia,* he said: "Their principal ornament is the bone which they thrust through the cartilage which divides the nostrils from each other. What perversion of taste could make them think this a decoration, or what could prompt them, before they had worn it or seen it worn, to suffer the pain and inconvenience that must of necessity attend it, is perhaps beyond the power of human sagacity to determine. As this bone is as thick as a man's finger, and between five and six inches long, it reaches quite across the face, and so effectually stops up both the nostrils that they are forced to keep their mouths wide open for breath, and snuffle so when they attempt to speak that they are scarcely intelligible even to each other. Our seamen, with some humor, called it their spritsail-yard; and, indeed, it

* "First Voyage," vol. ii., p. 633.

had so ludicrous an appearance that, till we were used to it, we found it difficult to refrain from laughter."

Eight years later, on his visit to the northwest coast of America, Captain Cook found precisely the same custom prevailing among the natives of Prince William's Sound, whose mode of life was in most other respects quite dissimilar to that of the Australians, and who belong ethnologically to a totally different branch of the human race.

In 1681 Dampier* thus describes a custom which he found existing among the natives of the Corn Islands, off the Mosquito coast, in Central America: "They have a Fashion to cut Holes in the Lips of the Boys when they are young, close to their Chin, which they keep open with little Pegs till they are fourteen or fifteen years old; then they wear Beards in them, made of Turtle or Tortoise-shell, in the Form you see in the Margin. The little Knotch at the upper end they put in through the Lip, where it remains between the Teeth and the Lip; the under Part hangs down over their Chin. This they commonly wear all day, and when they sleep they take it out. They have likewise Holes bored in their Ears, both Men and Women, when young, and by continual stretching them with great Pegs, they grow to be as big as a mill'd Five-shilling Piece. Herein they wear Pieces of Wood, cut very round and smooth, so that their Ear seems to be all Wood, with a little Skin about it."

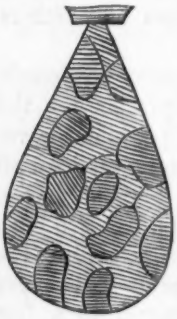


FIG. 2.

It is a remarkable thing that an almost exactly similar custom still prevails among a tribe of Indians inhabiting the southern part of Brazil—the Botocudos, so called from a Portuguese word meaning a plug or stopper. Among these people the lip-ornament consists of a conical piece of hard and polished wood, frequently weighs a quarter of a pound, and drags down, elongates, and everts the lower lip, so as to expose the gums and teeth, in a manner which to our taste is hideous, but with them is considered an essential adjunct to an attractive and correct appearance.

In the extreme north of America, the Esquimaux "pierce the lower lip under one to both corners of the mouth, and insert in each aperture a double-headed sleeve-button or dumb-bell-shaped labret, of bone, ivory, shell, stone, glass, or wood. The incision when first made is about the size of a quill, but, as the aspirant for improved beauty grows older, the size of the orifice is enlarged until it reaches the width of half to three quarters of an inch."† These operations appear to be practised only on the men, and are supposed to possess some significance other than that of mere ornament. The first piercing of the lip,

* "Voyage Round the World," edition 1717, vol. i., p. 32.

† H. H. Bancroft, "Native Races of the Pacific States of North America," vol. i., 1875.

which is accompanied by some solemnity as a religious feast, is performed on approaching manhood.

But the people who have carried these strange customs to the greatest excess are the Thlinkeets, who inhabit the southeastern shores of Alaska.* "Here it is the women who, in piercing the nose and ears, and filling the apertures with bones, shells, sticks, pieces of copper, nails, or attaching thereto heavy pendants, which drag down the organs and pull the features out of place, appear to have taxed their inventive powers to the utmost, and with a success unsurpassed by any nation

FIG. 3.—BOTOCUDO INDIAN. From Bigg-Wither's "Pioneering in South Brazil" (1878).

in the world, to produce a model of hideous beauty. This success is achieved in their wooden lip-ornament, the crowning glory of the Thlinkeet nation, described by a multitude of eye-witnesses. In all female free-born Thlinkeet children, a slit is made in the under lip, parallel with the mouth, and about half an inch below it. A copper wire, or a piece of shell or wood, is introduced into this, by which the wound is kept open and the aperture extended. By gradually introducing larger objects the required dimensions of the opening are produced. On attaining the age of maturity, a block of wood is inserted, usually oval or elliptical in shape, concave on the sides, and grooved like the wheel of a pulley on the edge in order to keep it in place. The dimensions of the block are from two to six inches in length, from one to four inches in width, and about half an inch thick round the edge, and it is highly polished. Old age has little terror in the eyes of a

* See Bancroft, *op. cit.*, vol. i., for numerous citations from original observers regarding these customs.

Thlinkeet belle; for larger lip-blocks are introduced as years advance, and each enlargement adds to the lady's social status, if not to her facial charms. When the block is withdrawn, the lip drops down upon the chin like a piece of leather, displaying the teeth, and presenting altogether a ghastly spectacle. The privilege of wearing this ornament is not extended to female slaves."

In this method of adornment the native Americans are, however, rivaled, if not eclipsed, by the negroes of the heart of Africa.

"The Bongo women" (says Schweinfurth*) "delight in distinguishing themselves by an adornment which to our notion is nothing less than a hideous mutilation. As soon as a woman is married, the operation commences of extending her lower lip. This, at first only slightly bored, is widened by inserting into the orifice plugs of wood, gradually increasing in size, until at length the entire feature is enlarged to five or six times its original proportions. The plugs are cylindrical in form, not less than an inch thick, and are exactly like the pegs of bone or wood worn by the women of Musgoo. By this means the lower lip is extended horizontally till it projects far beyond the upper, which is also bored and fitted with a copper plate or nail, and now and then by a little ring, and sometimes by a bit of straw, about as thick as a lucifer-match. Nor do they leave the nose intact; similar bits of straw are inserted into the edges of the nostrils, and I have seen as many as three of these on each side. A very favorite ornament for the cartilage between the nostrils is a copper ring, just like those that are placed in the nose of buffaloes and other beasts of burden for the purpose of rendering them more tractable. The greatest coquettes among the ladies wear a clasp, or cramp, at the corners of the mouth, as though they wanted to contract the orifice, and literally to put a curb upon its capabilities. These subsidiary ornaments are not, however, found at all universally among the women, and it is rare to see them all at once upon a single individual; the plug in the lower lip of the married women is alone a *sine quâ non*, serving as it does for an artificial distinction of race."

The slightest fold or projection of the skin furnishes an excuse for boring a hole, and inserting a plug or a ring. There are women in the country whose bodies are pierced in some way or other in little short of a hundred different places, and the men are often not far behind in the profusion with which this kind of adornment is carried out.

"The whole group of the Mittoo exhibits peculiarities by which it may be distinguished from its neighbors. The external adornment of the body, the costume, the ornaments, the mutilations which individuals undergo—in short, the general fashions—have all a distinctive character of their own. The most remarkable is the revolting, because unnatural, manner in which the women pierce and distort their lips; they seem to vie with each other in their mutilations, and their vanity

* "Heart of Africa," vol. i., p. 297.

in this respect, I believe, surpasses anything that may be found throughout Africa. Not satisfied with piercing the lower lip, they drag out the upper lip as well for the sake of symmetry.* . . . Circular plates, nearly as large as a crown-piece, made variously of quartz, of ivory, or of horn, are inserted into the lips that have been stretched by the growth of years, and then often bent in a position that is all but horizontal; and when the women want to drink, they have to elevate the upper lip with their fingers, and to pour the draught into their mouth.

"Similar in shape is the decoration which is worn by the women of Maganya; but, though it is round, it is a ring and not a flat plate; it is called *pelele*, and has no object but to expand the upper lip. Some of the Mittoo women, especially the Loobah, not content with

FIG. 4.—LOOBAH WOMAN. (From Schweinfurth's "Heart of Africa.")

the circle or the ring, force a cone of polished quartz through the lips as though they had borrowed the idea from the rhinoceros. This fashion of using quartz belemnites of more than two inches long is in some instances adopted by the men."

The traveler who has been the eye-witness of such customs may well add: "Even among these uncultured children of nature, human pride crops up among the fetters of fashion, which, indeed, are fetters in the worst sense of the word; for fashion in the distant wilds of Africa tortures and harasses poor humanity as much as in the great prison of civilization."

It seems, indeed, a strange phenomenon that in such different races, so far removed in locality, customs so singular—to our ideas so revolting and unnatural, and certainly so painful and inconvenient—should

* The mutilation of both lips was also observed by Rohlfs among the women of Kadje, in Segseg, between Lake Tchad and the Benwe.

either have been perpetuated for an enormous lapse of time, if the supposition of a common origin be entertained, or else have developed themselves independently.

These are, however, only extreme or exaggerated cases of the almost universal custom of making a permanent aperture through the lobe of the ear for the purpose of inserting some adventitious object by way of adornment, or even for utility, as in the man of the Island of Mangea, figured in Cook's "Voyages," who carries a large knife through a hole in the lobe of the right ear. Among ourselves, the custom of wearing ear-rings still survives, even in the highest grades of society, although it has been almost entirely abandoned by one half of the community, and in the other the perforation is reduced to the smallest size compatible with the purpose of carrying the ornament suspended from it.

The teeth, although allowed by the greater part of the world to retain their natural beauty and usefulness of form, still offer a field for artificial alterations according to fashion, which has been made use of principally in two distinct regions of the world and by two distinct races. It is, of course, only the front teeth, and mainly the upper incisors, that are available for this purpose. Among various tribes of negroes of Equatorial Africa, different fashions of modifying the natural form of these teeth prevail, specimens of which may be found in any large collection of crania of these people. One of the simplest consists of chipping and filing away a large triangular piece from the lower and inner edge of each of the central incisors, so that a gap is

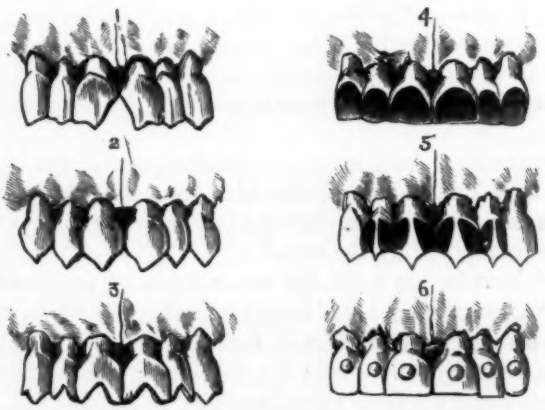


FIG 5.—UPPER FRONT TEETH ALTERED ACCORDING TO FASHION: 1, 2, 3, African; 4, 5, 6, Malay.

produced in the middle of the row in front (Fig. 5, 1). Another fashion is to shape all the incisors into sharp points, by chipping off the corners, giving a very formidable crocodilian appearance to the jaws (2); and another is to file out either a single or a double notch in the

cutting edge of each tooth, producing a serrated border to the whole series (3).

The Malays, however, excel the Africans, both in the universality and in the fantastic variety of their supposed improvements upon nature. While the natural whiteness of the surface of these organs is always admired by us, and by most people, the Malays take the greatest pains to stain their teeth black, which they consider greatly adds to their beauty. White teeth are looked upon with perfect disgust by the Dyaks of the neighborhood of Sarawak. In addition to staining the teeth, filing the surface in some way or other is almost always resorted to. The nearly universal custom in Java is to remove the enamel from the front surface of the incisors, and often the canine teeth, hollowing out the surface, sometimes, but not often, so deeply as to penetrate the pulp cavity (4). The cutting edges are also worn down to a level line with pumice-stone. Another, and less common, though more elaborate fashion, is to point the teeth, and file out notches from the anterior surface of each side of the upper part of the crown, so as to leave a lozenge-shaped piece of enamel untouched; as this receives the black stain less strongly than the parts from which the surface is removed, an ornamental pattern is produced (5). In Borneo a still more elaborate process is adopted: the front surface of each of the teeth is drilled near the center with a small round hole, and into this a plug of brass with a round or star-shaped knob is fixed (6). This is always kept bright and polished by the action of the lip over it, and is supposed to give a highly attractive appearance when the teeth are displayed.

Perhaps the strange custom, so frequently adopted by the natives of Australia, and of many islands of the Pacific, of knocking out one or more of the front teeth, might be mentioned here, but it is usually associated with some other idea than ornament or even mere fashion. In the former case it constitutes part of the rites by which the youth are initiated into manhood, and in the Sandwich Islands it is performed as a propitiatory sacrifice to the spirits of the dead.

The projection forward of the front upper teeth, which we think unbecoming, is admired by some races, and among the negro women of Senegal it is increased by artificial means employed in childhood.*

All these modifications of form of comparatively external and flexible parts are, however, trivial in their effects upon the body to those which I shall speak of next, which induce permanent structural alterations both upon the bony framework and upon the important organs within.

Whatever might be the case with regard to the hair, the ears, the nose, and lips, or even the teeth, it might have been thought that the actual shape of the head, as determined by the solid skull, would not have been considered a subject to be modified according to the fashion

* Hamy, "Revue d'Anthropologie," January, 1879, p. 22.

of the time and place. Such, however, is far from being the case. The custom of artificially changing the form of the head is one of the most ancient and widespread with which we are acquainted. It is far from being confined, as many suppose, to an obscure tribe of Indians on the northwest coast of America, but is found, under various modifications, at widely different parts of the earth's surface, and among people who can have had no intercourse with one another. It appears, in fact, to have originated independently, in many quarters, from some natural impulse common to the human race. When it once became an established custom in any tribe, it was almost inevitable that it should continue, until put an end to by the destruction either of the tribe itself, or of its peculiar institutions, through the intervention of some superior force, for a standard of excellence in form, which could not be changed in those who possessed it, was naturally followed by all who did not wish their children to run the risk of the social degradation which would follow the neglect of such a custom. "Failure properly to mold the cranium of her offspring gives to the Chinook matron the reputation of a lazy and undutiful mother, and subjects the neglected children to the ridicule of their young companions, so despotic is fashion." * It is related in the narrative of Commodore Wilkes's "United States Exploring Expedition," † that "at Niculuita Mr. Drayton obtained the drawing of a child's head, of the Walla Walla tribe (Fig. 6), that had just been released from its bandages, in order to secure its flattened shape. Both the parents showed great delight at the success they had met with in effecting this distortion."

FIG. 6.—FLAT-HEADED INDIAN CHILD.

Many of the less severe alterations of the form to which the head is subjected are undesigned, resulting only from the mode in which the child is carried or dressed during infancy. Thus habitually carrying the child on one arm appears to produce an obliquity in the form of the skull which is retained to a greater or less degree all through life. The practice followed by nomadic people of carrying their infants fastened to stiff pillows or boards, commonly causes a flattening of the occiput; and the custom of dressing the child's head with tightly fitting bandages, still common in many parts of the Continent, and even used in England within the memory of many living people, produces an elongated and laterally constricted form.‡ In France this is well known, and so com-

* Bancroft, *op. cit.*, vol. i., p. 238.

† Vol. iv., p. 388.

‡ After the lecture, a gentleman of advanced age showed me a circular depression round the upper part of his head, which he believed had been produced in this manner, as the custom was still prevailing at the time of his birth in the district of Norfolk of which he was a native.

mon is it in the neighborhood of Toulouse, that a special form of head produced in this manner is known as the "*déformation Toulousaine.*"

Of the ancient notices of the custom of purposely altering the form of the head, the most explicit is that of Hippocrates, who in his treatise, "De Aëris, Aquis et Locis," about 400 B. C., says,* speaking of the people near the boundary of Europe and Asia, near the *Palus Mœotis* (Sea of Azov): "I will pass over the smaller differences among the nations, but will now treat of such as are great either from nature or custom; and first, concerning the *Macrocephali.* There is no other race of men which have heads in the least resembling theirs. At first, usage was the principal cause of the length of their head, but now Nature coöperates with usage. They think those the most noble who have the longest heads. It is thus with regard to the usage: immediately after the child is born, and while its head is still tender, they fashion it with their hands, and constrain it to assume a lengthened shape by applying bandages and other suitable contrivances, whereby the spherical form of the head is destroyed, and it is made to increase in length. Thus, at first, usage operated, so that this constitution was the result of force; but in the course of time it was formed naturally, so that usage had nothing to do with it."

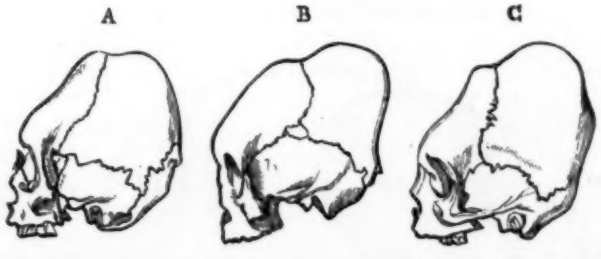


FIG. 7.—SKULLS ARTIFICIALLY DEFORMED ACCORDING TO SIMILAR FASHIONS: A, from an ancient tomb at Tiflis; B, from Titicaca, Peru. (From specimens in the Museum of the Royal College of Surgeons.) C, from the Island of Mallicollo, New Hebrides.

Here Hippocrates appears to have satisfied himself upon a point which is still discussed with great interest, and still not cleared up—the possibility of transmission by inheritance of artificially produced deformity. Some facts seem to show that such an occurrence may take place occasionally, but there is an immense body of evidence against its being habitual.

Herodotus also alludes to the same custom, as do, at later dates, Strabo, Pliny, Pomponius Mela, and others, though assigning different localities to the nations or tribes they refer to, and also indicating variations of form in their peculiar cranial characteristics.

Recent archæological discoveries fully bear out these statements. Heads deformed in various fashions, but chiefly of the constricted,

* Sydenham Society's edition, by Dr. Adam, vol. i., p. 207.

elongated shape, have been found in great numbers in ancient tombs in the very region indicated by Herodotus. They have been found near Tiflis, where as many as one hundred and fifty were discovered at one time, and at other places in the Caucasus, generally in rock-tombs; also in the Crimea, and at different localities along the course of the Danube; in Hungary, Silesia, in the south of Germany, Switzerland, and even in France and Belgium. The people who have left such undoubted evidence of the practice of deforming their heads have been supposed by various authors to have been Avars, Huns, Tartars, or other Mongolian invaders of Europe; but later French authors, who have discussed this subject, are inclined to assign them to an Aryan race, who, under the name of Cimmerians, spread westward over the part of Europe in which their remains are now found, in the seventh or eighth century before our era. As the method of deformation in European specimens is not always identical, it is by no means certain that the custom may not have been in use among more than one nation. Whether the French habit, scarcely yet extinct, of tightly bandaging the heads of infants, is derived from these people, or is of independent origin, it is impossible to say.

FIG. 8.—DEFORMED SKULL OF AN INFANT, who had died during the process of flattening; from the Columbia River. (Museum of the Royal College of Surgeons.)

FIG. 9.—ARTIFICIALLY FLATTENED SKULL OF ANCIENT PERUVIAN. (Museum of the Royal College of Surgeons.)

In Africa and Australia no analogous customs have been shown to exist, but in many parts of Asia and Polynesia, deformations, though usually only confined to flattening of the occiput, are common. Though often undesigned, it is done purposely, I am informed by Mr. H. B. Low, by the Dyaks, in the neighborhood of Sarawak. Sometimes, in the islands of the Pacific, the head of the new-born infant is merely pressed by the hands into the desired form, in which case it generally

soon recovers that which Nature intended for it. In one island alone, Mallicollo, in the New Hebrides, the practice of permanently depressing the forehead is almost universal, and skulls are even found constricted and elongated exactly after the manner of the Aymaras of ancient Peru.

Though the Chinese usually allow the head to assume its natural form, confining their attentions to the feet, a certain class of mendicant devotees appear to have succeeded to a remarkable extent in getting their skulls elongated into a conical form, if the figure in Picart's "Histoire des Religions," vol. iv., plate 131, is to be trusted.

America is, however, or rather has been, the headquarters of all these fantastic practices, and especially along the western coast, and mainly in two regions, near the mouth of the Columbia River in the north, and in Peru in the south. The practice also existed among the Indians of the southern part of what are now the United States, and among the Caribs of the West India Islands. In ancient Peru, before the time of the Spanish conquest, it was almost universal. In an edict of the ecclesiastical authorities of Lima, issued in 1585, three distinct forms of deformation are mentioned. Notwithstanding the severe penalties imposed by this edict upon parents persisting in the practice, the custom was so difficult to eradicate that another injunction against it was published by the Government as late as 1752.

FIG. 10.—POSTERIOR VIEW OF CRANIUM, deformed according to the fashion of flattening, with compensatory lateral widening. (Museum of the Royal College of Surgeons.)

In the West Indies, and the greater part of North America, the custom has become extinct with the people who used it; but the Chinook Indians, of the neighborhood of the Columbia River, and the natives of Vancouver Island, continue it to the present day, and this is the last stronghold of this strange fashion, though under the influence of European example and discouragement it is rapidly dying out. Here the various methods of deforming the head and their effects have

been studied and described by numerous travelers. The process commences immediately after the birth of the child, and is continued for a period of from eight to twelve months, by which time the head has permanently assumed the required form, although during subsequent growth it may partly regain its proper shape. "It might be supposed," observes Mr. Kane, who had large opportunities of watching the process, "that the operation would be attended with great suffering, but I never heard the infants crying or moaning, although I have seen their eyes seemingly starting out of the sockets from the great pressure; but, on the contrary, when the thongs were loosened and the pads removed, I have noticed them cry until they were replaced. From the apparent dullness of the children while under the pressure, I should imagine that a state of torpor or insensibility is induced, and that the return to consciousness occasioned by its removal must be naturally followed by a sense of pain."

Nearly, if not all, the different fashions in cranial deformity, observed in various parts of the world, are found associated within a

FIG. 11.—CRANIUM OF KOSKEEMO INDIAN, Vancouver Island, deformed by circular constriction and elongation. (Museum of the Royal College of Surgeons.)

very small compass in British Columbia and Washington Territory, each small tribe having often a particular method of its own. Many attempts have been made to classify these various deformities, but as they mostly pass insensibly into one another, and vary according as the intention has been carried out with a greater or less degree of perseverance and skill, it is not easy to do so. Besides the simple occipital and the simple frontal compressions, all the others may be grouped into two principal divisions. First (Figs. 8 and 9), that in which the skull is flattened between boards or other compressors, applied to the forehead and back of the head, and as there is no lateral

pressure, it bulges out sideways to compensate for the shortening in the opposite direction (Fig. 10). This form is very often unsymmetrical, as the flattening boards, applied to a nearly spherical surface, naturally incline a little to one side or the other; and when this once commences, unless great care is used, it must increase until the very curious oblique flattening so common in these skulls is produced. This is the ordinary form of deformity among the Chinook Indians of the Columbia River, commonly called "Flat-heads." It is also most frequent among the Quichuas of Peru.

The second form of deformity (Figs. 7, 11, and 12) is produced by constricting bandages of deer's hide, or other similar material, encircling the head behind the ears, usually passing below the occiput behind, and across the forehead, and again across the vertex, behind the coronal suture, producing a circular depression. The result is an elongation of the head, but with no lateral bulging, and with no deviation from bilateral symmetry. This was the form adopted with trifling modifications by the *Macrocephali* of Herodotus, by the Aymara Indians of Peru, and by certain tribes, as the Koskeemos, of Vancouver Island. The "*déformation Toulousaine*" is a modification of the same form.

FIG. 12.—POSTERIOR VIEW OF CRANIUM, deformed according to the fashion of circular constriction and elongation. (Museum of the Royal College of Surgeons.)

The brain, of course, has had to accommodate itself to the altered shape of the osseous case which contained it; and the question naturally arises, whether the important functions belonging to this organ are in any way impaired or affected by its change of form. All observations upon the living Indians who have been subjected to it, concur in showing that if any modification in mental power is produced, it must be of a very inconsiderable kind, as no marked difference has been detected between them and the neighboring tribes which have not adopted the fashion. Men whose heads have been deformed to an extraordinary extent, as Concomly, a Chinook chief, whose skull is preserved in the museum at Haslar Hospital, have often risen by their own abilities to considerable local eminence, and the fact that the relative social position of the chiefs, in whose families the heads are always deformed, and the slaves on whom it is never permitted, is constantly maintained, proves that the former evince no decided inferiority in intelligence or energy.

Although the American Indians, living a healthy life in their native wilds, and under physical conditions which cause all bodily lesions to occasion far less constitutional or local disturbance than is the case

with people living under the artificial conditions and the accummulated predisposition to disease which civilization entails, thus appear to suffer little, if at all, from this unnatural treatment, it seems to be otherwise with the French, on whom its effects have been watched by medical observers more closely than it can have been on the savages in America. "Dr. Foville proves, by positive and numerous facts, that the most constant and the most frequent effects of this deformation, though only carried to a small degree, are headaches, deafnesses, cerebral congestions, meningitis, cerebritis, and epilepsy; that idiocy or madness often terminates this series of evils, and that the asylums for lunatics and imbeciles receive a large number of their inmates from among these unhappy people."* For this cause the French physicians have exerted all their influence, and with great success, to introduce a more rational system in the districts where the practice of compressing the heads of infants prevailed.

I will now pass from the head to the extremities, and shall have little to say about the hands, for the artificial deformities practiced upon those members are confined to chopping off one or more of the fingers, generally of the left hand, and usually not so much in obedience merely to fashion, as part of an initiatory ceremony, or an expiation or oblation to some superior, or to some departed person. Such practices are common among the American Indians, some tribes of Africans, the Australians, and Polynesians, especially those greatest of all slaves of ceremonial, the Feejeeans, where the amputation of fingers is demanded to appease an angry chieftain, or voluntarily performed on the occasion of the death of a relative as a token of affection.

On the other hand, the feet have suffered more, and altogether with more serious results to general health and comfort from simple conformity to pernicious customs, than any other part of the body. But on this subject, instead of relating the unaccountable caprices of the savage, we have to speak only of people who have already advanced to a tolerably high grade of civilization, and to include all those who are at the present time foremost in the ranks of intellectual culture.

The most extreme instance of modification of the size and form of the foot in obedience to fashion, is the well-known case of the Chinese women, not entirely confined to the upper classes, but in some districts pervading all grades of society alike. The deformity is produced by applying tight bandages round the feet of the girls when about five years old. The process is an extremely painful one, and its results are not only an alteration in the relative position of the growing bones and other structures, but an arrest of their development, so that they remain permanently in a stunted or atrophied condition. The alterations of form consist in two distinct processes: 1. Bending the four

* Gosse, "Essai sur les Déformations artificielle du Crane," "Annales d'Hygiène publique," 2 ser., tome iv., p. 8.

outer toes under the sole of the foot, so that the first or great toe alone retains its normal position, and a narrow point is produced in front: 2. Compressing the roots of the toes and the heel downward and toward one another so as greatly to shorten the foot, and produce a deep transverse fold in the middle of the sole (Fig. 14). The whole has now the appearance of the hoof of some animal rather than a human foot, and affords a very inefficient organ of support, as the peculiar tottering gait of those possessing it clearly shows.

But strange as this custom seems to us, it is only a slight step in excess of what the majority of people in Europe subject themselves and their children to. From personal observation of a large number of feet of persons of all ages and of all classes of society in our own country, I do not hesitate to say that there are very few, if any, to be

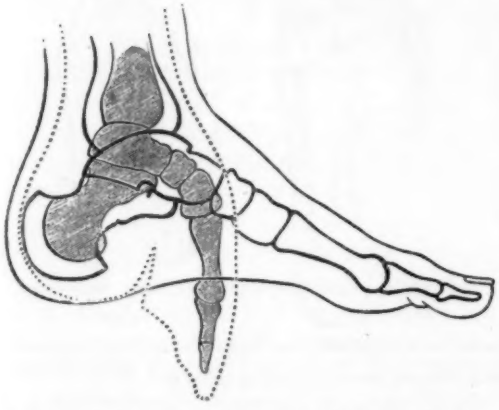


FIG. 13.—SECTION OF NATURAL FOOT WITH THE BONES, AND A CORRESPONDING SECTION OF A CHINESE DEFORMED FOOT. The outline of the latter is dotted, and the bones shaded.

FIG. 14.—SOLE OF CHINESE WOMAN'S FOOT.

met with that do not, in some degree, bear evidence of having been subjected to a compressing influence more or less injurious. Let any one take the trouble to inquire into what a foot ought to be. For external form look at any of the antique models—the nude Hercules Farnese or the sandaled Apollo Belvedere; watch the beautiful freedom of motion in the wide-spreading toes of an infant; consider the wonderful mechanical contrivances for combining strength with mobility, firmness with flexibility; the numerous bones, articulations, ligaments; the great toe, with seven special muscles to give it that versatility of motion which was intended that it should possess—and then see what a miserable, stiffened, distorted thing is this same foot, when it has been submitted for a number of years to the "improving" process to which our civilization condemns it: the toes all squeezed and flattened against each other; the great toe no longer in its normal position, but turned outward, pressing so upon the others that one or

more of them frequently has to find room for itself either above or under its fellows; the joints all rigid, the muscles atrophied and powerless; the finely formed arch broken down; everything which is beautiful and excellent in the human foot destroyed, to say nothing of the more serious evils which so generally follow—corns, bunions, ingrowing nails, and all their attendant miseries.

Now, the cause of all this will be perfectly obvious to any one who compares the form of the natural foot with the last upon which the shoemaker makes the covering for that foot. This, in the words of

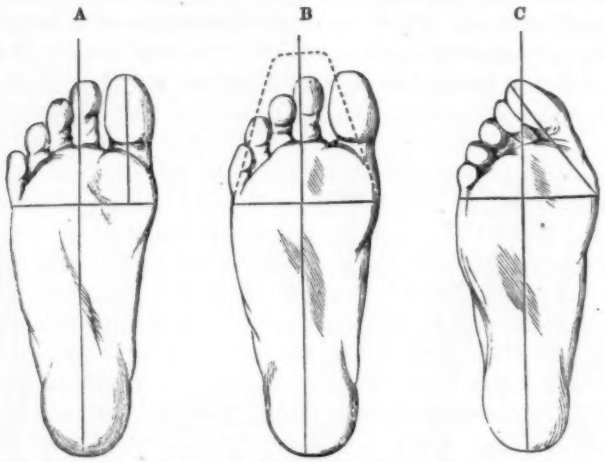


FIG. 15—A, natural form of the sole of the foot, the great toe parallel to the axis of the whole foot; B, the same, with outline of ordinary fashionable boot; C, the necessary modification of the form of the foot consequent upon wearing such a boot.

the late Mr. Dowie, "is shaped in front like a wedge, the thick part or instep rising in a ridge from the center or middle toe, instead of the great toe, as in the foot, slanting off to both sides from the middle, terminating at each side and in front like a wedge; that for the inside or great toe being similar to that for the outside or little toe, as if the human foot had the great toe in the middle and a little toe at each side, like the foot of a goose!" The great error in all boots and shoes made upon the system now in vogue in all parts of the civilized world lies in this method of construction upon a principle of bilateral symmetry. A straight line drawn along the sole from the middle of the toe to the heel will divide a fashionable boot into two equal and similar parts, a small allowance being made at the middle part, or "waist," for the difference between right and left foot. Whether the toe is made broad or narrow, it is always equally inclined at the sides toward the middle line, whereas in the foot there is no such symmetry. The first or inner toe is much larger than either of the others, and its direction perfectly parallel with the long axis of the foot. The second toe may be a little larger than the first, as generally represented in

Grecian art, but it is more frequently shorter; the other rapidly decrease in size (Fig. 15, A). The modification which must have taken place in the form of the foot and direction of the toes before such a boot can be worn with any approach to ease is shown at C. Often it will happen that the deformity has not advanced to so great an extent, but every one who has had the opportunity of examining many feet, especially among the poorer class, must have met with many far worse. The two figured (Fig. 16), one (C) from a laboring workingman, the other (A and B) from a working-woman, both patients at a London

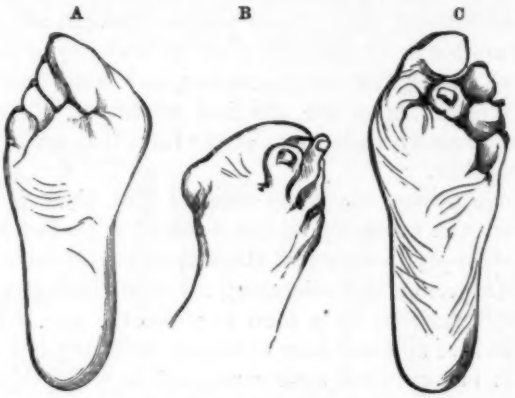


FIG. 16.—ENGLISH FEET DEFORMED BY WEARING IMPROPERLY SHAPED SHOES. (From Nature.)

hospital, are very ordinary examples of the European artificial deformity of the foot, and afford a good comparison with the Chinese. It not unfrequently happens that the dislocation of the great toe is carried so far that it becomes placed almost at a right angle to the long axis of the foot, lying across the roots of the other toes.

The changes that a foot has to undergo in order to adapt itself to the ordinary shape of a shoe could probably not be effected unless commenced at an early period, when it is young and capable of being gradually molded into the required form. It seems perfectly marvelous that any one who had ever looked at a healthy pair of human feet could have thought of the possibility of wearing a stiff, unyielding shoe of identical form for both right and left, and yet the very trifling difference which is at present allowed is a comparatively modern innovation, and is even now too frequently disregarded, especially where most needed, as in the case of children.

The loss of elasticity and motion in the joints of the foot, as well as the wrong direction acquired by the great toe, are not mere theoretical evils, but are seriously detrimental to free and easy progression, and can only be compensated for in walking by a great expenditure of muscular power in other parts of the body, applied in a disadvantageous manner, and consequently productive of general weari-

ness. The laboring-men of this country, who from their childhood wear heavy, stiff, and badly shaped boots, and in whom, consequently, the play of the ankle, feet, and toes is lost, have generally small and shapeless legs and wasted calves, and walk as if on stilts, with a swinging motion from the hips. Our infantry soldiers also suffer much in the same manner, the regulation boots in use in the service being exceedingly ill adapted for the development of the feet. Much injury to the general health—the necessary consequence of any impediment to freedom of bodily exercise—must also be attributed to this cause. Since some of the leading shoemakers have ventured to deviate a little from the conventional shape, those persons who can afford to be specially fitted are better off as a rule than the majority of poorer people, who, although caring less for appearance, and being more dependent for their livelihood upon the physical welfare of their bodies, are obliged to wear ready-made shoes of the form that an inexorable custom has prescribed.

No sensible person can really suppose that there is anything in itself ugly, or even unsightly, in the form of a perfect human foot; and yet all attempts to construct shoes upon its model are constantly met with the objection that something extremely inelegant must be the result. It will, perhaps, be a form to which the eye is not quite accustomed; but we all know how extremely arbitrary is Fashion in her dealings with our outward appearance, and how anything which has received her sanction is for the time considered elegant and tasteful, while a few years later it may come to be looked upon as positively ridiculous. That our eye would soon get used to admire a different shape may be easily proved by any one who will for a short time wear shoes constructed upon a more correct principle, when the prevailing pointed shoes, suggestive of cramped and atrophied toes, become positively painful to look upon.

Only one thing is needed to aggravate the evil effect of a pointed toe, and that is the absurdly high and narrow heel so often seen now on ladies' boots, which throws the whole foot into an unnatural position in walking, produces diseases well known to all surgeons in large practice, and makes the nearest approach yet effected by any European nation to the Chinese custom which we generally speak of with surprise and reprobation. And yet this fashion appears just now on the increase among people who boast of the highest civilization to which the world has yet attained.

But when, in spite of all the warnings of common sense and experience,* we continue to torture and deform our horses' mouths and necks with tight bearing-reins, as injurious, as useless, and as ugly as any of these customs we practice on ourselves, and all for no better reason, we may well say with Dr. Johnson, "Few enterprises are so hopeless as a contest with fashion."

* See "Bits and Bearing-Reins," by Edward Fordham Flower. Cassell & Co., 1879.

I must speak last upon one of the most remarkable of all the artificial deformities produced by adherence to a conventional standard, and one which comes very near home to many of us.

It is no part of the object of the present discourse to give a medical disquisition upon the evils of tight-lacing, though much might be said of the extraordinary and permanent change of form and relative position produced by it, not only on the bony and cartilaginous framework of the chest, but also in the most important organs of life contained within it, changes far more serious in their effects than those of the Chinook's skull and brain, or the Chinese woman's foot. It is only necessary to compare these two figures (Figs. 17 and 18), one

FIG. 17.—TORSO OF THE STATUE OF VENUS OF MILO.

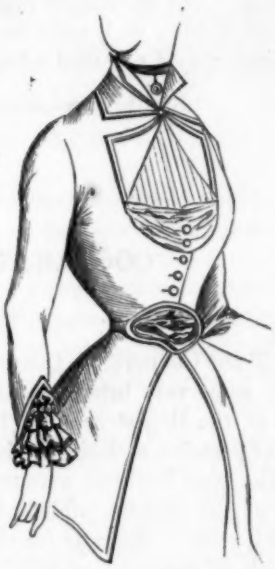


FIG. 18.—PARIS FASHION, MAY, 1880.

acknowledged by all the artistic and anatomical world to be a perfect example of the natural female form, to be convinced of the gravity of the structural changes that must have taken place in such a form, before it could be reduced so far as to occupy the space shown in the second figure, an exact copy of one of the models now held up for imitation in the fashionable world. The wonder is not that people suffer, but that they continue to live, under such conditions.

It is quite possible, or even probable, that some of us may think the latter the more beautiful of the two. If any should do so, let us pause to consider whether we are sure that our judgment is sound on the subject. Let us remember that to the Australian the nose-peg is an admired ornament, that to the Thlinkeet, the Botocudo, and the

Bongo negro, the lip dragged down by the heavy plug and the ears distended by huge disks of wood are things of beauty, that the Malay prefers teeth that are black to those of the most pearly whiteness, that the Western Indian despises the form of a head not flattened down like a pancake, or elongated like a sugar-loaf, and then let us carefully ask ourselves whether we are sure that in leaving nature as a standard of the beautiful, and adopting a purely conventional criterion, we are not falling into an error exactly similar to that of all these people whose tastes we are so ready to condemn.

The fact is that, in admiring such distorted forms as the constricted waist and symmetrically pointed foot, we are simply putting ourselves on a level in point of taste with those Australians, Botocudos, and negroes. We are taking fashion, and nothing better, higher, or truer, for our guide; and, after the various examples brought forward this evening, may I not well ask—

"Seest thou not what a deformed thief this fashion is?"

COÖPERATION IN ENGLAND.

By GEORGE ILES.

AT the Coöperative Congress, held in Newcastle-on-Tyne, last May, some very interesting statistics were presented. The latest report of the Registrar is for 1878, and shows the membership of British coöperative societies to have been 560,703, having transacted during the year business amounting to $102,820,000. In 1861—the first year of the reports published by the Registrar—the membership was 48,184, with a business for that year of $7,360,000. This remarkable growth of coöperation within recent years has brought it from the obscurity of a theory, held by the general public to be either impracticable altogether, or practicable only within special and narrow limits, to the importance of a power which is transforming in appreciable measure the entire retail trade of Great Britain, and which, at the last election, had aroused an antagonism which excluded from Parliament two well-known publicists of high character and ability.

The coöperative movement, as far as it has gone, has been chiefly directed toward so improving the ordinary methods of retail trade as to confer moral benefit and material profit upon the working-classes. The wastes of our present plans of retail distribution are very obvious: our streets swarm with inconsiderable shops, repetitions of one another, and maintained at an enormous aggregate expense. Competition has far exceeded the bounds within which it does good, by spurring industry and inciting emulation; without regard to the strictly

limited wants of a community, shopkeepers begin business in cities and towns where overtrading already prevails, and the consequence is loss to the investors and demoralization all round. Excessive competition has led to a system of giving credit, which supports dishonest debtors at industry's cost, and keeps multitudes of book-keepers, collectors, and lawyers employed at the charge of productive labor. Furthermore, under existing methods, the losses to society from adulteration continue and increase from year to year. The delusive appearance of cheapness is often bought at a ruinous price. Owen used to declare that an adulteration of pure long-fiber cotton with but one seventh of coarse short staple lessened the wearing value of the fabric one half, and, in the paint-trade, sulphate of baryta is largely mixed with white-lead, yet the sulphate has no covering power whatever as a pigment, and absorbs much valuable oil. The standard of an article, such as coffee, sugar, or paint, once lowered by fraudulent admixture, can scarcely ever be raised again, as the common run of people are poor judges of what they buy, and hesitate to pay the price of a pure and sound article, instead of the current price for really inferior wares which look as well.

All this struck some needy flannel-weavers of Rochdale nearly forty years ago, and, by weekly subscriptions of twopence each, under the name of the "Equitable Pioneers," they began a small store for the sale of provisions and groceries; they did not attempt, at first, to sell dry goods or other merchandise subject to the caprices of fashion, or the equal caprices of a variety of customers, whose tastes might not be well judged by the managing committee. These Rochdale weavers plainly saw that all that keeps the big shops in a town from completely eating up the petty ones is the uncertain and fluctuating character of their custom; so they agreed among themselves to stick to their store for what it could sell them, which they could safely do, as they managed it honestly and well. Once, too, when their flour-mill went badly for a time, they kept on using the ill-made flour until they had all put right, showing their confidence in ultimate success by cheerfully bearing temporary loss. From twopenny beginnings, the Rochdale store has grown until, at the end of 1878, it numbered 10,187 members, having transacted during the year a business of $1,450,000, with a profit of $257,000, the expenses being reduced by good management to two per cent. Although the "Equitable Pioneers" were by no means the first society formed in England for coöperative distribution, yet, as one of the earliest among existing societies, its pre-eminent success has made it the model for imitation wherever a new society is being established, or it is necessary to rectify the imperfect working of a society already in business. The "History of the Society of Equitable Pioneers to 1857," written by George Jacob Holyoake, attracted so much interest that a second era of their history to 1878 has been given to the world by the same author, who has also written

the "History of Coöperation," in two volumes, which all should read who wish to know how the movement arose, who labored for it, and what its ultimate aims are.

The rules of the Rochdale society are accepted by the chief exponents of coöperation as being thoroughly wise and judicious. The society sells its goods at the current rates charged by retail merchants, thus avoiding the direct underselling of shopkeepers, and withholding the profits of their system from non-subscribers. Buyers are given metal tokens, representing the value of the cash they pay in. Quarterly stock is taken, and the rate of profit ascertained; then, after paying subscribers to capital their interest at five per cent. per annum, buyers are paid in cash, or credited in the ledger, as they choose, with the amount of their dividends, computed on the tokens brought in. The majority of buyers have their dividends credited to them, thus virtually establishing a savings-bank account, and affording the society means for the extension of its business. Connected with the store are a corn-mill, a shoe-factory, and a soap-factory.

The capital of the coöperative societies is, as a rule, nominally withdrawable. As large investments are often made in real estate, machinery, and other property not readily salable, the necessity has become evident that the trading capital of a society should consist in transferable shares—like those of a joint-stock company—while the deposit capital can only be withdrawable at call. Thus an element of stability is introduced, which prevents a temporary panic or stress of bad times from winding up a really sound society's business.

The societies are managed by committees usually elected for a year, and annual statements of affairs are required by the Government. To watch over the collective interest of the societies, they appointed in 1870 a Central Coöperative Board, with its office in Manchester: this body has obtained for coöperation all needful legislation, and the removal as far as possible of obstacles to its right action. The exemption of the societies as such from income-tax, the limitation of the liability of members for the debts of a society to the sum unpaid upon the shares standing in their names, and an easy method of bequeathing shares without expense, were assured by the Central Committee to which the Central Board succeeded. The Board since its formation has prepared and published the land, building, and mortgage rules, necessary to be observed by societies; and a series of general business rules well thought out and thoroughly tested by experience, whereby new associations may avoid the weaknesses and errors which have been the causes of coöperative failures in the past. For the further assistance of the societies scattered throughout the country, a general secretary of legal attainments is engaged to give such legal and practical advice as from time to time may be sought. The Central Board has established at Manchester "The Coöperative News," a weekly journal, and in addition it circulates broadcast coöperative tracts and pamphlets.

In 1864 a new and important application of the principle of association was made in Manchester—a wholesale society was founded, to supply some hundred and fifty stores. No more serious difficulty had hitherto been met by small new societies than that of buying well. Often remote from the great centers of production, and purchasing in small quantities through a committee or manager of defective knowledge of qualities and prices, much hard-earned money was wasted. Now, in buying through the Wholesale, a society avails itself of the services of expert buyers, who obtain, through their vast purchases, goods at the lowest current prices. Stores are not obliged, as they used to be, to buy more goods than they immediately require, to reach the minimum prices of the market; hence they can carry on business with less capital than they needed formerly. To detect adulterations and determine the quality of wares offered to it, the Wholesale Society employs an analytical chemist. The business of this vast organization now serves more than five hundred societies; it employs buyers in eleven towns and cities in England, Ireland, France, and America. Its subscribed capital is $686,000; the shares, which are five pounds sterling each, are issued on condition that an affiliated society takes out one for each ten members belonging to it, increasing the number annually as its members increase. One shilling per share must be paid on application, on which five per cent. interest is allowed; the remainder can be paid up at once, or be paid up by accumulation of dividends and interest. The sales of the Wholesale Society for the year ending January 11, 1880, were $13,166,545; yet the managers state that these large figures could have been more than doubled had all the societies in the kingdom been joined to the Wholesale, and had they bought from it all the supplies which, with advantage to themselves, they might have taken. The Wholesale Society transacts a large banking business, and this its best advisers deem should be placed upon a separate footing, with its special board of direction. Glasgow has a counterpart to the great Manchester establishment—the Glasgow Wholesale Society has a connection of one hundred and thirty-seven Scottish societies, and during 1879 did a business of $3,066,500.

As instituted at Rochdale, and in scores of other towns and cities, coöperation has been intended by its leaders not only to save to the working-classes the sums commonly absorbed by the wastes, expenses, and profits of ordinary retail trading; it has been designed to train workmen in thrift, in thoughtfulness for the future, and by the gradual accumulation of capital to enable them either to become self-employing, or to own shares in the manufacturing or mining company which may engage them. Some of the societies have provision for building cottages for members out of the dividends credited to them. At Derby and elsewhere hundreds of homes for workingmen have been bought in this way. Coöperation has diffused much knowledge of business, and interest in it, among classes who used formerly to know

and care very little about it. The committee and general meetings are usually well attended, and often give scope and opportunity to ability which might without coöperation have lain dormant. Many useful suggestions in times of difficulty have been made by men and women whose only school has been that of hardship and penury.

Societies which strictly follow the Rochdale type set apart annually a portion of their profits for educational purposes, and as a result free libraries and news-rooms are attached to some of the larger stores; the love of information, however, is sometimes wanting in a society whose constant habit is to declare fat dividends. Such societies have averted from them the upward-looking countenances of true coöperators, who regard the lack of food for the mind as demanding at least the ample relief bestowed upon physical hunger.

The citizens of the great metropolis of England have not been ready learners of the men of Rochdale. In the vast extent of London workmen usually live at a distance from their workshops and factories, and the variety of industries is so great that the combinability of the workmen in a town of moderate size and tolerably uniform manufacturing production finds no parallel in London. Then, too, the varied excitements and amusements of the modern Babylon are held to make its work-people more volatile than their provincial brethren, and therefore less susceptible of becoming united and working together. Whatever may be the causes, the fact remains that coöperation scarcely exists in London among the poor, and is mainly confined to the vast associations of the middle and upper classes. The chief of these conduct the Civil-Service stores, the first of which was founded in 1864 by the Post-Office employees. Since 1864 other departments of the Civil Service have joined their *confrères* of the Post-Office, and the business transacted at their warehouses has become enormous. The principles of the London stores are essentially different from those of the provincial ones. In stores of the Rochdale type, capital as such receives no share in profits, it obtains only its interest at five per cent.; in London, subscribers to the capital stock of the Coöperative Associations need not be buyers at all, yet they share in the profits of the business; the plan being to set prices upon the goods sold as much below those of ordinary retailers as will enable the working expenses to be paid and give a reasonable return to the capital embarked. There is no provision in these associations for the accumulation of the sums saved by buying of them, and the underselling of the shopkeepers is direct, and not indirect, as in the provincial stores, where the current retail prices are charged, and the saving comes in the shape of a dividend every six or twelve months. The shopkeeping interest has been much more resentful of the London stores than of provincial ones. In dispossessing shopkeepers of their business, and subjecting them to hardship by employing the economical methods of coöperation, the factory operatives of Lancashire and Yorkshire had the justification of their

pressing needs ; no such justification, however, does the London shopkeeper hold that the people of wealth and title have when they desert his counter for the Civil-Service stores. He regards his profits as inalienable rights, and has at times published plaints on his losses of business in the daily press, at once sordid and silly. The Civil-Service Society has been imitated by several large associations among the army and navy, the clergy and the Nonconformists, who derive many noteworthy advantages from their coöperation. United, and being able to give life and fire insurance companies large lines of business without the usual expense of solicitation, members are enabled to take out policies in companies of standing at a discount. Combination, too, has reduced the charges for legal and medical advice, and whether in making his will, or having a tooth drawn, or having the *accouchement* of his wife performed, the London coöperator is better off than other men.

Although the stores, as the coöperative warehouses are called, transact but a very small fraction of the retail trade of London, they are finding imitators so fast that an entire change in the methods of doing business is being brought about. The old way of selling goods on credit and charging in prices a percentage large enough to cover the loss and expenses entailed by the system can not stand before the economy of buying and selling for cash. Then the vast scale of the business of the stores enables them to buy on the best terms directly from producers and manufacturers, and the charges of rent, taxes, and management, are proportionately much less than in small independent concerns. The percentage of total expense to business transacted is but 5¼ on an average for all the British societies, and is perhaps somewhat less in the London stores. Their business is rendered in a large measure uniform by being maintained by a known circle of customers with wants of a fairly calculable character ; and large sums are saved by premises not being needed on a street of high rents for chance custom's sake ; and the stores do not require to expend, when once established, anything for advertisements or other solicitation. The chief retail streets of London contain frequent announcements of "Coöperative prices," "Discounts for cash," and "Discounts increasing with the extent of a purchase"—all evidencing attempts to employ the economical features of coöperation by firms competing with the stores.

No coöperator, however sanguine, believes that the stores will eventually supersede all retail shops. Taste and skill will always secure independence, and a better reward than falls to the lot of those who supply in an ordinary unexcellent way the general wants of their customers. An artistic cabinet-maker or upholsterer, as well as a really good tailor or shoemaker, will never need to offer discounts to retain business ; but all the many things which one factory can turn out as well as another, or one importer can buy with as much facility as his

neighbor, must inevitably be distributed, as the struggle for the means of existence grows sharper, with the greatest economy possible. The pleasures of shopping may lose some of their attraction when the cost of keeping up shops depending upon chance custom becomes understood, and when the managers of stores undergo such evolution as to enable them to display their goods with taste and effect. Some of the great English stores look as if all inducing to purchase by tasteful appeals to the eye were among the things to be left behind.

The stores have drawn attention to a principle which may yet find wide development—the organization of supply and demand, so that the uncertainties and difficulties of modern business may be made less oppressive than they are now felt to be. When a particular retail store has its permanent body of purchasers whose money conducts the concern, stocks of goods can be laid in with little of the doubt and uncertainty which must vex the ordinary shopkeeper and subject him to inevitable loss; the same principle leads to yet further economy when, as at Manchester, a wholesale society supplies a stated and large number of stores for their fairly predictable wants. A steadying of the fluctuations of production would occur were wholesale societies federated to manufacturing and importing societies; the whole series conferring mutual benefits among the members, and depriving the speculator, the corner-maker, and the fraudulent bankrupt of their spoils. Such is the ideal of coöperation, to which at a distance, toilsome indeed, its leaders are endeavoring to come in practice. Could the coöperative principle by the integrity and stability of a people spread throughout its trade, the perplexities and losses of business would be enormously reduced. The area over which a merchant's customers are now scattered usually prevents him from knowing much of their personal characters or circumstances. Competition, with its too cheap credit, has made it rarely possible for a wholesale merchant or manufacturer to ask his customer upon what grounds he should be trusted. The knowledge which in olden times used to be directly sought between man and man is now usually obtained through irresponsible commercial agencies, which, however honestly and ably managed, can not and should not take the place of direct inquiry of a trader seeking credit by the merchant or manufacturer who trusts him. The intermediation, too, of the commercial traveler, who does so much of the business of to-day, weakens the sense of responsibility felt at its height when merchant and customer meet face to face; and the extent of bankruptcy within recent years has undoubtedly been widened by the constant and undue solicitation to buy on the part of these commercial travelers, who are interested more in effecting large sales than in ascertaining the soundness of their customers.

The extension of railroads and other means of travel and transportation, by increasing the mutual invasion by merchants of each other's territory, has had the effect of making constant and expensive solicita-

tion necessary to the maintenance of a "connection." The good will of a business year by year declines in value in the market. In some measure needless competition arises from the improved modern facilities of locomotion by virtue of a curious illusion: merchants and manufacturers seem to think that the mere aggregation of the small districts in which business was done in the past increases the area of the total market, as if taking down fences affected the aggregate acreage of contiguous farms. If the factories and warehouses engaged in the supply of the home market were distributed throughout Great Britain in sections of equal population, their over-supply would be plain.

For all the baffling difficulties which the enlargement of the area of trade has introduced into business, and all the parasitical expenses which have fastened themselves upon it, coöperation offers a remedy—a remedy, however, only to be applied as intelligence and trustworthiness advance. The costly war and waste of isolated competition are signs and tokens that men can not trust each other, and have not mutual forbearance enough to combine for common ends in securing for themselves competence and content.

The leaders of English coöperation, while busily engaged in forwarding their plans of distribution, are constantly striving to apply their principles to the more important field of production. If the identification of the interests of buyer and seller is fraught with advantage, still greater advantage awaits the successful fusion of the interests of capital and labor. Up to the present time, however, the experiments in this direction have not been promising, and the case of production now seems to stand where the case of distribution did forty or fifty years ago. Workmen are not educated up to it yet; neither, it would seem, are the men of capital. The Messrs. Briggs, at their Whitewood collieries, divided for several years a percentage of their profits among their employees, leaving for their own share a sum larger than they believed would have come to them under the usual system of hiring. A plan similar to that of the Messrs. Briggs has been followed by Messrs. Fox, Head & Co., at Middleborough. Another method adopted extensively in Yorkshire and Lancashire is for workmen to invest their savings in shares of joint-stock manufacturing companies. The vast business now conducted by coöperative stores has in some measure opened up a path for coöperative manufacturing, but to an extent very limited in proportion to the business transacted, and in a manner very remote from perfect coöperation. At the Leicester shoe-factory and elsewhere the workmen are hired for wages, just as ordinary capitalists hire, and have no share in profits. The difficulties of managing a store are not few, but they are far less troublesome than conducting production on purely coöperative principles. When every workman in a concern has a voice and vote, in the present state of morals and intelligence, the disputes are interminable as to their respective rates of payment, the proportions of profit which shall be divided between capital,

labor, and buyer, and the general policy of the business. Many coöperative workshops have through these disputes failed miserably, and either fallen into individual hands or been converted into joint-stock companies. These failures of coöperative production have done somewhat to allay the bitterness of class-feeling among workmen toward their employers. They find how rare really good business ability is, and how necessary to success it is. They find that it is requisite at times to guard intentions secretly, and to practice a boldness quite impossible when hundreds of interests exist to be consulted, timid about deputing full powers either to managers or committees.

Workmen who have toiled to save a few pounds, and have lost them in a coöperative workshop, have awakened to the fact that the gains of the capitalist are not merely interest on his money, but also payment for the exercise of his judgment, foresight, and executive ability, without which his wealth, however great, would fast melt away in the strifes of business. It is true that coöperation seeks to abolish many of the hazards which make modern business require unusual talent for its management; judgment will be relieved from many questions when credit is curtailed, and consumers are federated to a factory conducted by their own capital and directors; yet in the actual present, while coöperation still remains in its infancy, the existing conditions of competition beset capitalists with difficulties of which only experience has made workmen aware.

MODERN ASPECTS OF THE LIFE-QUESTION.*

By Professor GEORGE F. BARKER.

The number of roots in our equation of life increases the difficulty of solving it, but by no means permits the acceptance of the lazy assumption that it is altogether insoluble or reduces a sagacious guess to the level of the prophecy of a quack.—Haughton.

THE discovery of new truth is the grand object of scientific work. The exultation of feeling which comes from the possession of a fact, which now, for the first time, he makes known to men, must ever be the reward of the scientific worker. As investigators and as students of science we are met here to-day at this our annual session. Each of us during the past year has been endeavoring to push outward further into the unknown, the boundary of present knowledge. When, therefore, we thus meet together, it is fitting that, from time to time, our attention should be called to the progress which has been

* Address of the retiring President of the American Association for the Advancement of Science, delivered at the Boston meeting, August 25, 1880.

made along some one of the various lines of research, and to the milestones which mark the epochs of advance along the way which science has traveled. Moreover, we may profitably sum up at such times the work done in particular directions, and encourage ourselves with prospective and retrospective glances. In these summings up, however, a difficulty arises. The range of modern scientific thought includes an immense area. The field of knowledge is already so vast that, seen from the vertical distance necessary to make a wide survey, that small portion of it which is familiar to any one individual is scarcely visible. In consequence, to use a mechanical figure, the solid contents of a man's acquirements being given, the depth thereof is inversely as the area covered. He, therefore, who undertakes to speak even for one single department of science distributes his stock of knowledge over so broad a surface that in places it must become dangerously thin. It is, therefore, with a very keen sense of the temerity involved in the undertaking that I ask your attention, during the hour allotted me, to some points which appear to me to have been recently gained in the discussion of the question of life.

My friend and predecessor, Professor Marsh, opened his excellent address at Saratoga with the question, "What is Life?" In a somewhat different sense I too ask the same question. But I fear it is only to echo his reply, "The answer is not yet." The result, however, can not long be doubtful. "A thousand earnest seekers after truth seem to be slowly approaching a solution." And, though the *ignis fatuus* of life still dances over the bogs of our misty knowledge, yet its true character can not finally elude our investigation. The progress already made has hemmed it in on every side; and the province within which exclusively vital acts are now performed narrows with each year of scientific research.

What now are we to understand by the word "Life" in this discussion? A noteworthy parallel is disclosed in the progress of human knowledge between the ideas of life and of force. Both conceptions have advanced, though not with equal rapidity, from a stage of complete separability from matter to one of complete inseparability. Life is now universally regarded as a phenomenon of matter, and hence, of course, as having no separate existence. But there still exists a certain vagueness in the meaning of the term "life." Two distinct senses of this word are in use; the one metaphysical, the other physiological. The former, synonymous with mind and soul, at least in the higher animals, has been evolved from human consciousness; the latter has arisen from a more or less careful investigation of the phenomena of living beings. It need scarcely be said that it is in the sense last mentioned that the word "life" is used in science. The conception represents simply the sum of the phenomena exhibited by a living being.

Moreover, the progress which has been made in the solution of the life-question has been gained chiefly by investigation of special func-

tions. But the functions of a vital organism are themselves vital. What, then, is the meaning of "vital" as applied to a function? Fortunately, the answer is not difficult. "Life," says Küss, the distinguished Strasburg physiologist, "is all that can not be explained by chemistry or physics." Guided by such a definition the work of the physiological investigator is simple. He has only to test each separate operation which he finds going on in the organism, and to declare whether it be chemical or physical. If it be either, then, since each function is non-vital, the entire organism must be non-vital also. Hundreds of able investigators, provided with the most effective appliances of research, are now in full cry after the life-principle. Naturally, a vast amount of collateral knowledge is accumulated in the process. The quantitative as well as the qualitative relations of things are fixed and many important facts are collected.

With the object in view thus clearly defined, we are not surprised that great progress has been made. A vital process, like the catalytic ones of the older chemistry, was found by such research to be simply a process which, for want of sufficient investigation, is not yet understood. While therefore, undoubtedly, much work yet remains to be done in the realm still called vital, the prophetic vision is already bright which will witness the last traces of inexplicable phenomena vanish and the words expressing them relegated to the limbo of the obsolete.

As a first result of recent work, the living organism has been brought absolutely within the action of the law of the Conservation of Energy. Whether it be plant or animal, the whole of its energy must come from without itself, being either absorbed directly or stored up in the food. An animal, like a machine, only transforms its energy. Lavoisier's Guinea-pig placed in the calorimeter gave as accurate a heat-return for the energy it had absorbed in its food as any thermic engine would have done. But the parallel goes further. The mechanical work of an engine is measured by the loss of its heat and not of its substance. So the mechanical or intellectual work of a living being is measured by the amount of food rather than the amount of tissue which is burned. The energy evolved daily by the human body would raise it to a height of about six miles.

But, besides heat, work may be the outcome of the organism; and this through the agency of the muscles. Their absolute obedience to mechanical law in their mode of action has been admirably established by Haughton. The work a muscle does, it does in contracting. It is to the mechanism of muscle-contraction that we are indebted for another illustration of our subject.

When work is done by a muscle in contracting, three changes are observed to take place in its tissue: First, there is a loss of its electric tension; second, there is an evolution of heat in it; and, third, carbon dioxide appears there, and its reaction, before neutral, becomes acid.

Matteucci was the first to observe and to call attention to the remarkable similarity, in structure and in the mechanism of operation, between striated muscular fiber and the electric organ of certain fishes. Recently, Marey has repeated and extended his observations. In structure, the electric organ is made up, like the muscle, of columnar masses each separable transversely into vesicular sections. In a torpedo weighing seventy-three pounds, there were 1,182 of these columns, with 150 sections, on an average, in each. In the muscles which bend the forearm, there are 798,000 fibrillæ. As to the mechanism, alike in muscle and in electric organ, an electric current stimulates action on opening and on closing the circuit, but not when it is flowing; the same phenomena take place in both with the direct and with the inverse current; both are reflex; stimulation of the electric nerve produces discharge, as that of the motor nerve causes muscular shock; an entire paralysis follows nerve-section; curare paralyzes both; and tetanus results in both from rapid currents or from strychnine.

Still more striking analogies are furnished by the investigation of the susurrus or muscular sound, first noticed in 1809 by Wollaston. This sound is produced by all muscles when in the state of contraction, the pitch of the note being not far from thirty vibrations per second. It is evidently only the intermittent discharge of the muscular fiber. A single excitation produces a muscular shock. As this production requires from eight to ten hundredths of a second, it is evident that, if another stimulus be applied before the first has disappeared, the two will coalesce; and when twenty per second reach the muscle it becomes permanently contracted or tetanized. By means of a very sensitive myograph, Marey has found that in voluntary contraction the motor nerves are the seats of successive acts, each of which produces an excitation of the muscle. In 1877 Marey examined similarly the discharge of the torpedo, and found a most complete correspondence between it and muscular contraction. Since electric tension disappears from a muscle during contraction, is not the evidence conclusive that muscular contraction, like the discharge of the electric organ of the torpedo, is an electrical phenomenon?

Granting electric discharge to be the cause of muscle-contraction, what is its origin? That it is not carried to the muscle by the nerves follows from the fact that a muscle will still contract when deprived of all its nerve-fibers. It must therefore be generated within the muscle itself. To reach a solution of the problem we must obviously follow the analogies of its production elsewhere.

Perhaps no single question in physics has been more keenly discussed than this one of the origin of electric charge. The memorable conflict between Galvani and Volta, between animal electricity and the electricity of metallic contact, succeeded by the even more triumphant overthrow of the latter and the establishment ultimately by

Faraday of the electro-chemical theory—these are facts fresh in all our memories. The justice of time, however, in this case, if it has been tardy, has been none the less sure. The experiments of Thomson have vindicated Volta and established the contact theory as a *vera causa*. And, more curiously still, it now appears to be proved that both contact and chemical action underlie the production of that very animal electricity so stoutly battled for by Galvani and his associates.

Volta's experiments to prove that a difference of potential is developed by the contact of two heterogeneous metals were not crucial. But Thomson, repeating them with the aid of more delicate apparatus, has shown that, whenever copper and zinc are brought in contact, the copper becomes negative to the zinc. In proof that the chemical action of atmospheric moisture was not the cause of the phenomenon, he showed that, when a drop of water served to connect the copper and the zinc, no charge at all was produced. The fact may therefore be regarded as established, as the result of numerous and varied experiments, that a difference of electrical potential is always developed at the surfaces of contact of heterogeneous media. Not only is this true of solids in contact with solids, but also of solids in contact with liquids, and of liquids in contact with each other. Of course, the production of electricity by contact must result from a loss of energy elsewhere. In the opinion of Cumming, it is the loss of energy which is owing to the unsymmetrical swinging of the molecules on the two sides of the surfaces of contact, which reappears as difference of potential between the solids or as the energy of electrical separation.

But we may carry the sequence yet another step backward. The energy which is thus lost at the surfaces of separation must be heat, and this junction must be cooled thereby. Thus the production of thermo-electricity is seen only to be a special case of a general law, a view to which the well-known Peltier effect gives support. In this phenomenon, when two metals are joined together in the form of a ring and one junction is heated, a current is produced which cools the other junction. From a study of these conditions, Thomson has concluded that the absorption of heat in a thermo-electric circuit varies for different metals with the direction of the current. Thus in iron, the current from hot to cold absorbs heat, while in copper the current which absorbs heat is from cold to hot. In entire accordance with these results are the conclusions recently reached by Hoorweg. Whenever two conductors come into contact, motion of heat results in the development of electricity, the current produced existing at the cost of heat at one part of the point of contact, and evolving heat at the other for a result. Hence all voltaic currents are thermo-currents.

To return to the muscle, it must now be apparent that the electrical charge which appears in its fiber may have its origin in so purely a physical cause as the contact of the heterogeneous substances of which the tissue is built up; the maintenance of this charge being effected

by chemical changes going on constantly in the substance of the muscle, by which the carbon dioxide is produced, which is shown to be a measure of the work done.

Conceding, now, that muscular contraction is of the nature of an electric discharge, by what mechanism is the contraction effected? A string of electrified masses, like a muscular fibril, would seem at first to oppose the view now advanced. Such a row of particles would indeed attract each other when electrified and shorten the length of the whole. But the force of contraction would increase as the length diminished; whereas the fact in the case of the muscle is precisely the reverse. Two theories have been advanced to account for the result. The first, proposed by Marey, likens the muscular fiber to a string of india-rubber which, when stretched, contracts upon the application of heat, thus transforming heat directly into work. The other, brought forward and strongly supported by Radcliffe, explains contraction by direct electric charge. Each fiber of the muscle together with its sheath constitutes a veritable condenser, the charge upon the exterior being positive and upon the interior negative. When a charge is communicated to the fiber, lateral compression results from the attraction of the electricities of opposite name, and, since the volume remains constant, elongation is the consequence—precisely as a band of caoutchouc, having strips of tin-foil upon its sides, may be shown to elongate when charged like a condenser. In this view of the matter the normal condition of the muscle is one of charge, of elongation. Contraction results from the simple elasticity of the muscle itself, the function of the nerve being only that of a discharger. Whether this theory represents the actual fact or not, in all its details, it is supported by the existence of *rigor mortis*, by the continued relaxation of muscle during the flow of the current, by the cessation of contraction on the free access of blood, and by many other phenomena otherwise difficult to explain.

From this brief review, does it not seem probable that the phenomenon of muscular contraction may be satisfactorily accounted for without the assumption of "vital irritability," so long invoked? May it not be conceded that the theory that muscular force has a purely physical origin is at least as probable as the vital theory?

Time would fail me to discuss the many other phenomena of the living body which have been found on investigation to be non-vital. Digestion, which Prout said it was impossible to believe was chemical, is now known to take place as well without the body as within it, and to result from non-vital ferments. Absorption is osmotic, and its selective power resides in the structure of the membrane and the diffusibility of the solution. Respiration is a purely chemical function. Oxyhæmoglobin is formed wherever hæmoglobin and oxygen come in contact, and the carbon dioxide of the serum exchanges with the oxygen of the air according to the law of gaseous diffusion. Circulation

is the result of muscular effort both in the heart and the capillaries, and the flow which takes place is a simple hydraulic operation. Even coagulation, so tenaciously regarded as a vital process, has been shown to be purely chemical, whether we adopt the hypothesis of Schmidt that it results from the union of two proteids, fibrinogen and fibrinoplastic substance, or the later theory of Hammarsten, that fibrine is produced from fibrinogen by the action of a special ferment.

One function yet remains which can not be altogether omitted from our consideration. This function is that of the nervous system. In structure, this system is well known to us all. In composition, it is made up essentially of a single substance, discovered by Liebreich and called protagon, the specific characters of which have lately been confirmed by Gamgee. In function, the nerve-cell and the nerve-fiber are occupied solely in the reception and the transmission of energy, which is in all probability electrical. There is evidently a close analogy between the nerve and the muscle, the axis cylinder like the fibrilla being composed of cells, and having a positive electric charge upon the exterior surface, which has a tension of one tenth of a volt. Haughton attributes *tinnitus aurium* to the discharge of nerve-cells.

The only objection raised to the electrical character of nerve-energy is based upon its slow propagation. Though thirty years ago Johannes Müller predicted that the velocity of nerve transmission never could be measured, yet Helmholtz accomplished the feat very soon afterward. His results, like those of subsequent experimenters, show that the velocity of propagation of the nervous influence along a nerve, like that of electric transmission, is only about twenty-six to twenty-nine metres in a second. But it should be borne in mind, as Lovering has pointed out, that electricity has no velocity, in any proper sense ; that, since the appearance of an electrical disturbance at the end of a conductor depends upon the production of a charge, the time of this appearance will be a joint function of the electrostatic capacity of the conductor and of its resistance. Since each of these values is directly proportional to length, it follows that the time of transmission will vary as the square of the length of the conductor. While, therefore, in Wheatstone's experiment, he found that electricity required rather more than one millionth of a second to pass through one quarter of a mile of wire, it does not follow that it would traverse 288,000 miles in one second, as he assumed. Indeed, as Lovering has shown, its actual velocity would be only two hundred and sixty-eight miles in an entire second. Hence the marvelous discrepancies which have been observed in the results of experiments made to determine the velocity of electricity on long wires are explained.

In the nerve itself, therefore, the velocity of transmission may be supposed to be the less as its resistance is greater. Now, Weber has shown that animal tissues in general have a conductivity only one fifty-millionth of that of copper. And Radcliffe found that a single

inch of the sciatic nerve of a frog measured 40,000 ohms, a resistance eight times that of the entire Atlantic cable. In experimenting to confirm the above law of velocity, Gaugain measured the time of transmission of the electric current through a cotton thread 1·65 metre long, and found it to be eleven seconds. Two similar threads placed consecutively, thus forming a conductor twice as long, required forty-four seconds for the passage of the current, or four times as long. From these data the velocity in the short thread is at the rate of only 0·15 metre in one second; and in the long one only about half this rate, of course. Hence the fact that the energy of nerve moves at the rate of only twenty-eight metres per second is really no proof that it is not electricity.

The higher functions of the nerve-cell, those connected with mental processes, is a field too vast to be entered at this time. The double telegraph line of nerve, motor and sensor in their effect, but, as Vulpian has proved, precisely alike in function, are the avenues of ingress and egress. Every sensory impression is received by the *thalami optici;* every motor stimulus is sent out from the *corpora striata.* In the acts denominated reflex, the action goes from the spinal cord and is automatic and unconscious. Should the impression ascend higher to the sensory ganglia, the action is now conscious, though none the less automatic. Finally, should deliberation be required before acting, the message is sent to the hemispheres by the sensory ganglia, and will operates to produce the act. Based on principles which can be established by investigation, a true psychology is coming into being, developed by Bain, Maudsley, Spencer, and others. A physiological classification of mental operations is being formed which uses the terms of metaphysical psychology, but in a more clearly defined sense. Emotion, in this new science, is the sensibility of the vesicular neurine to ideas—memory, the registration of stimuli by nutrition. Reflection is the reflex action of the cells in their relation to the cerebral ganglia. Attention is the arrest of the transformation of energy for a moment. Ratiocination is the balancing of one energy against another. Will is the reaction of impressions outward. And so on through the list.

Among the physical aspects of the mind-question, the problem of the quantitative changes which take place in the organism is a very curious and interesting one. That the energy of the brain comes from the food will be disputed by no one in these days. Hence, the brain must act like a machine and transform energy. There is, then, a purely physiological representation of mental action, concerned with forces which are known and measurable. The researches of Lombard long ago showed the concomitant heat of mental action. Recent researches are equally interesting, which show that mental operations are not instantaneous, but require a distinct time for their performance. By accurate chronographic measurement, Hirsch has shown that an irritation on the head is answered by a signal with the hand only after one

seventh of a second; that a sound on the ear is indicated by the hand in one sixth of a second; and that, when light irritates the eye, one fifth of a second elapses before the hand moves. The mechanism of such a process is the following: Suppose the sound "A" is heard by the ear. After a latent period it is translated to some nerve-cells and hence to the brain. From the brain it goes to other cells, ganglion-cells, and to other nerves, and then to the different muscles of the chest and larynx, and then follows the audible response "A." Now, since this whole process requires only one sixth of a second, the question arises, How much of it is psychical? To answer it, the experiment is repeated, but with this difference, that the particular sound to be used is unknown to the experimenter. Before the sound can be repeated by him, therefore, a distinct act of discrimination is required, and the time taken is longer. Calling the time in the first experiment *a*, and in the second *b*, the difference *b*—*a* is the time required for two distinct actions; one, that of distinguishing the sound, and the other, that of willing the corresponding movement. If, now, it be agreed that only the sound "A" shall be responded to when called, these may be separated, since, no other sound being responded to, the latter action is eliminated. If the time now required be called *c*, the difference *c*—*a* represents the time required for forming a judgment, and *c*—*b* the time required for a volition. In making these measurements, Donders used an instrument devised by him, called a noëmotachograph, and also a modification of it, called a noëmotachometer. By these instruments different points of the body can be irritated, different sounds can be produced, and different colors or letters can be shown, all by the electric spark. By subtracting the simple physiological time from the time given in any experiment, the time necessary for recognition may be obtained. By an addition to the apparatus, a second stimulus may be made to follow the first, either on the same or on a different sense, thus enabling the time necessary for a simple thought to be determined. As a result of his experiments, Donders found that the value *b*—*a* in the case of a simple dilemma was seventy-five thousandths of a second, this being the time required for recognition and subsequent volition. In the same way *c*—*a* has been shown to be forty thousandths of a second, being the time required for simple recognition; there are left thirty-five thousandths of a second as the time required for volition. Moreover, by independent measurement with the noëmotachometer, exactly the same time, one twenty-fifth of a second, is found necessary to enable a judgment to be formed about the priority of two impulses acting on the same sense. If they act on different senses, more time is necessary. So, also, more time is required to recognize a letter by seeing its form than by hearing its sound. A man of middle age, then, thinking not so very quickly, requires one twenty-fifth of a second for a simple thought.

Another important fact concerning nervous action is that its amount

may be measured by the quantity of blood consumed in its performance. Dr. Mosso, of Turin, has devised an apparatus called the plethysmograph—drawings of which were exhibited at the London Apparatus Exhibition of 1876—designed for measuring the volume of an organ. The forearm, for example, being the organ to be experimented on, is placed in a cylinder of water and tightly inclosed. A rubber tube connects the interior of the cylinder with the recording apparatus. With the electric circuit, by which the stimulus was applied to produce contraction, were two keys, one of which was a dummy. It was noticed that, after using the active key several times, producing varying current strengths, the curve sank as before on pressing down the inactive key. Since no real effect was produced, the result was caused solely by the imagination, blood passing from the body to the brain in the act. To test further the effect of mental action, Dr. Pagliani, whose arm was in the apparatus, was requested to multiply 267 by 8, mentally, and to make a sign when he had finished. The recorded curve showed very distinctly how much more blood the brain took to perform the operation. Hence the plethysmograph is capable of measuring the relative amount of mental power required by different persons to work out the same mental problem. Indeed, Mr. Gaskell suggests the use of this instrument in the examination-room, to find out, in addition to the amount of knowledge a man possesses, how much effort it causes him to produce any particular result of brain-work. Dr. Mosso relates that, while the apparatus was set up in his room in Turin, a classical man came in to see him. He looked very contemptuously upon it and asked of what use it could be, saying that it couldn't do anybody any good. Dr. Mosso replied, "Well, now, I can tell you by that whether you can read Greek as easily as you can Latin." As the classicist would not believe it, his own arm was put into the apparatus and he was given a Latin book to read. A very slight sinking of the curve was the result. The Latin book was then taken away and a Greek book was given him. This produced, immediately, a much deeper curve. He had asserted before that it was quite as easy for him to read Greek as Latin, and that there was no difficulty in doing either. Dr. Mosso, however, was able to show him that he was laboring under a delusion. Again, this apparatus is so sensitive as to be useful for ascertaining how much a person is dreaming. When Dr. Pagliani went to sleep in the apparatus, the effect upon the resulting curve was very marked indeed. He said afterward that he had been in a sound sleep, and remembered nothing of what passed in the room—that he had been absolutely unconscious; and yet, every little movement in the room, such as the slamming of a door, the barking of a dog, and even the knocking down of a bit of glass, were all marked on the curves. Sometimes he moved his lips and gave other evidences that he was dreaming; they were all recorded on the curve, the amount of blood required for dreaming diminishing that in

the extremities. The emotions, too, left a record. When only a student came into the room, little or no effect appeared in the curve; but, when Professor Ludwig himself came in, the arteries in the arm of the person in the apparatus contracted quite as strongly as upon a very decided electrical stimulation.

In an address of the retiring President of this Association, delivered but a few years ago, I find this sentence: "Thought can not be a physical force, because thought admits of no measure." In the light of the rapid advances lately made in investigating mental action, we see that in two directions at least, in its rate of action and of its relative energy, we may already measure thought, as we measure any other form of energy, by the effects it produces.

Passing now to the consideration of the general question of the transformation of energy which is effected by living beings, attention may be called to one or two points in general physics, as bearing upon its solution. The great law of the dissipation of energy, as modified by Thomson from the statement of Clausius, is thus stated: "The entropy of the universe tends to zero." In other words, the energy of the universe available for transmutation is approaching extinction. This conclusion is based upon the fact that while every form of energy can be completely converted into heat, heat can not be completely converted into other forms of energy, nor these into each other. Hence it arises that energy is being gradually dissipated as heat. Moreover, since transformation can only result when heat passes from a higher to a lower temperature, it follows that, when that perfect equilibrium of temperature is reached toward which events are tending, there can be no other energy than heat, and this absolutely inconvertible, irrecoverable. To apply this law to the present case, the muscle, for example, is a machine for transforming the energy of food into work. Since, consequently, this conversion is not complete, it follows that heat must appear as a necessary result of muscular action. The heat of animal life, consequently, is not heat especially provided; it is simply the heat which inevitably results from an incomplete conversion of energy.

Again, the form of chemical action thus far assumed by physiologists to account for the energy of the living animal has been combustion. But the science of thermo-chemistry, as developed in late years by Berthelot and Thomson, has proved that direct union of chemical substances may not only not evolve heat, but may actually absorb it. It appears, too, that thermal changes accompany all forms of chemical change, those of decomposition and exchange as well as those of synthesis. The animal absorbs highly complex substances as food, capable of innumerable stages of retrogressive metamorphosis before elimination. In each of these stages heat is evolved, being the energy successively stored up by the plant when it repeated these stages in the inverse order.

Another point of interest has reference to the modern views of capillarity. In 1838 J. W. Draper showed that capillarity is an electrical phenomenon. Quite recently, Lippmann has developed and extended this view and fully confirmed it. Whenever the free surface of a liquid, curved by capillary action, is electrified it changes its form; and conversely, when such a surface is made by mechanical means to change its form, an electromotive force is developed. Based upon this principle Lippmann constructed a capillary reversible engine and an extremely sensitive capillary electrometer. The former, when a current of electricity was applied to it, developed mechanical work and ran as a motor. When turned by hand, it became an electromotor. In the animal organism there are it is true but a few free surfaces where this action can take place. But Gore has shown that the same phenomenon appears between two liquids in contact, their boundary being altered in character by electrification. Indeed, when we consider the production of electricity by osmose, and of heat and electricity both by imbibition, both capillary phenomena, the wonder is not that so much energy is evolved by the organism, but that it is so little. If the physical and chemical changes which take place within the body took place without it, there would be an abundant evolution of energy. Can we doubt that these changes are the cause of the energy exhibited by the organism?

Thus far, when we have spoken of a living being, we have had reference to the organism as a whole, and this of a rather complex kind. In this view of the case, however, we find that biological microscopists do not agree with us. "The cell alone," says Küss, "is the essentially vital element." Says Beale: "There is in living matter nothing which can be called a mechanism, nothing in which structure can be discerned. A little transparent, colorless material is the seat of these marvelous powers or properties by which the form, structure, and function of the tissues and organs of all living things are determined." And again, "However much organisms and their tissues in their fully formed state may vary as regards the character, properties, and composition of the formed material, all were first in the condition of clear, transparent, structureless, formless living matter." So Ranvier: "Cellular elements possess all the essential vital properties of the complete organism." And Allman, in his address as President of the British Association last year, is still more explicit. "Every living being," he says, "has protoplasm as the essential matter of every living element of its structure. . . . No one who contemplates this spontaneously moving matter can deny that it is alive. Liquid as it is, it is a living liquid; organless and structureless as it is, it manifests the essential phenomena of life. . . . Coextensive with the whole of organic nature—every vital act being referable to some mode or property of protoplasm—it becomes to the biologist what the ether is to the physicist." From these quotations it would seem that even in the highest

animal there is nothing living but protoplasm or germinal matter, "transparent, colorless, and, as far as can be ascertained by examination with the highest powers of the microscope, perfectly structureless. It exhibits these same characters at every period of its existence." Neither the contractile tissue of the muscle, the axis-cylinder of the nerve, nor the secreting cell of the gland, is living, according to Beale. Hence it would be fair to draw the inference that no vital force should be required to explain the phenomena of the non-living matter of the body, such as the contraction of the muscle or the function of the nerve. If this be conceded, it is a great point gained; since the phenomenon of life becomes vastly simplified when we have to account for it only as exhibited in this one single form of living matter, protoplasm. In describing its properties, Allman includes this remarkable mobility, these spontaneous movements, and says: "They result from its proper irritability, its essential constitution as living matter. From the facts there is but one legitimate conclusion, that life is a property of protoplasm." Beale, however, will not allow that life is "a property" of protoplasm. "It can not be a property of matter," he says, "because it is in all respects essentially different in its actions from all acknowledged properties of matter." But the properties of bodies are only the characters by which we differentiate them. Two bodies having the same properties would only be two portions of the same substance. Because life, therefore, is unlike other properties of matter, it by no means follows that it is not a property of matter. No dictum is more absolute in science than the one which predicates properties upon constitution. To say that this property exhibited by protoplasm, marvelous and even unique though it be, is not a natural result of the constitution of the matter itself, but is due to an unknown entity, a *tertium quid*, which inhabits and controls it, is opposed to all scientific analogy and experience. To the statement of the vitalist that there is no evidence that life is a property of matter, we may reply with emphasis that there is not the slightest proof that it is not.

Chemistry tells us that complexity of composition involves complexity of properties. The grand progress which organic chemistry has made in recent times has been owing to the distinct recognition of the influence of structure upon properties. Isomerism is one of its most significant developments. The number of possible isomers increases enormously with the complexity of the molecule. Granted that we now know several of the proteid group of substances: how many thousands may there be yet to know? Bodies of such extreme complexity of constitution may well have an indefinite number of isomers. Not only does Chemistry not say that there can not be such a thing, but she encourages the expectation that there will yet be found the precise proteid of which the changes of protoplasm are properties. The rapid march of recent organic synthesis makes it quite certain

that every distinct chemical substance of the living body will ultimately be produced in the laboratory; and this from inorganic materials. Given only the exact constitution of a compound, and its synthesis follows. When, therefore, the chemist shall succeed in producing a mass constitutionally identical with protoplasmic albumen, there is every reason to expect that it will exhibit all the phenomena which characterize its life; and this equally whether protoplasm be a single substance or a mixture of several closely allied substances.

But here a word should be said concerning a remarkable physical condition assumed by matter in organized beings. Graham, in 1862, drew the sharp line which separates colloid from crystalloid matter. "His researches have required," says Maudsley, "a change in our conception of solid matter. Instead of the notion of inert, impenetrable matter, we must substitute the idea of matter which in its colloid state is penetrable, exhibits energy, and is widely susceptible to external agents. This sort of energy is not a result of chemical action, for colloids are singularly inert in all ordinary chemical relations, but is a result of its unknown molecular constitution; and the undoubted existence of colloidal energy in organic substances, which are usually considered inert and called dead, may well warrant the belief of its larger and more essential operation in organic matter in the state of instability of composition in which it is when under the condition of life. Such energy would then suffice to account for the simple uniform movements of the homogeneous substance of which the lowest animal consists, and the absence of any differentiation of structure is a sufficient reason for the absence of any localization of function and of the general uniform reaction to local impressions." Graham himself says: "The colloidal state may be looked upon as the probable primary source of the force appearing in the phenomena of vitality." The colloidal condition is the dynamical state of matter; the crystalloidal the static. The former, which is the rule in the organic kingdom of nature, is the exception in the inorganic. Aluminum and ferric hydrates, silicic acid, and a few other inorganic substances, exist in the colloid condition. From analogy there would seem to be but little doubt that the colloid state of these bodies differs from their crystalloid state merely in the size of the molecule. In other words, opal, which is colloid silica, is a polymer of quartz. If this theory be true, there can be no doubt of the vastly greater complexity of a colloidal proteid molecule than of a crystalloid one. Now, it is a very significant fact, in this connection, that not a single organic colloid has ever been synthesized. Gelatine, which is one of the best examples of a colloid, has a comparatively simple structure. And, although Gibbs showed, many years ago, that gelatine was probably an amido-derivative of the sugar group, yet no inverse process has yet given us this substance. That matter in the crystalloid and the colloid forms may be chemically identical, differing only in the size of its molecule, may

be quite possible. But it is also possible that the difference may be a physical one. To produce the colloid state from the crystalloid is by no means beyond the power of science. We qualify our previous statement, then, only so far as to say that when the chemist produces a body in the colloidal form, having the identical constitution of protoplasm, there is every reason to believe that it will have the properties of protoplasm.

The important question now arises whether, since the protoplasm of animals is identical with that of vegetables, and the latter is the food of the former, any protoplasm whatever is vitalized by the animal as such. That this identity exists would seem satisfactorily established. Though the protoplasm of vegetables is inclosed within a cellulose bag, it is only a closely imprisoned rhizopod. In the Nitella, it shows all its characteristic irritability, and from Vaucheria it escapes to exhibit all its amœboid movements. Spores swim about by cilia or flagella, and the cell-division of the one kingdom is the same as that of the other. In plants, however, protoplasm seems to be associated with chlorophyl, whose function was for a long time supposed to be to decompose carbon dioxide under the influence of sunlight. But Draper in 1843 showed that this decomposition took place before the chlorophyl was formed. Recent researches have shown that the function of chlorophyl is wholly protective. The assimilative power of the protoplasm reaches its maximum in the orange and yellow rays. Now, Bert has shown that the absorption band in the chlorophyl spectrum is in the exact position of this maximum. Hence, Gautier believes that this substance acts as a regulator of plant respiration, the greater or less amount of luminous energy thus absorbed and transformed being utilized by the protoplasm and stored up. Growth and cell-division, however, are independent of orange light and hence of chlorophyl. In the higher plants these functions are performed by a separate and deep-lying set of cells. But, in the lower, the same cell discharges both functions, assimilation going on in it during the day, and growth chiefly at night. Sachs had already proved that the maximum growth of plants takes place just before daylight, and the minimum in the afternoon. This retarding action of sunlight upon growth is as curious as it is unexpected. It now appears that in orange light plants assimilate—absorb carbon dioxide and evolve oxygen—but do not grow—are not heliotropic ; while in blue light they are strongly heliotropic, but do not give off oxygen. Chlorophyl, however, is not confined to vegetables ; infusoria, hydras, and certain planarian worms are green from the presence of this substance, and Geddes has shown that such animals placed in the sunlight give off a gas which is more than half oxygen. These cells, moreover, contain starch-granules.

A still more striking evidence of this intimate relationship has been developed by Darwin, in his researches upon insectivorous plants. Not only do these plants possess a mechanism for capturing

insects, but they secrete a gastric juice which digests them. Nägeli has shown the presence of pepsin in yeast-cells, and attention has lately been called by Wurtz and others to the juice of the *Carica papaya*, which contains a pepsin-like substance capable of peptonizing fibrine completely. Moreover, there is the closest similarity between diastase and ptyaline; and the milk of the cow-tree, recently examined by Boussingault and found to resemble cream closely in composition, shows the presence of an emulsifying agent in the vegetable kingdom analogous to pancreatine in the animal.

Another most curious proof of the identity of animal and vegetable protoplasm has been given by Claude Bernard, who has shown that both are alike sensitive to the influence of anæsthetics. A sensitive plant exposed to ether no longer closed its leaflets when touched. Assimilation and growth, as well as germination, are arrested by chloroform. The yeast-plant when etherized no longer decomposes sugar to produce alcohol and carbon dioxide; while the inversive and non-vital ferment still acts to convert the cane-sugar into glucose; precisely as under these circumstances the diastasic ferment converts the starch of the seed into sugar. By arresting anæsthetically the process by which carbon dioxide is absorbed and oxygen evolved, the true respiratory process, being less affected, now appears; and Schützenberger has proved that the fresh cells of the yeast-plant breathe like an aquatic animal.

It would seem, then, that the protoplasmic life of animals is identical with that of plants; a certain measure of destructive metamorphosis taking place in each, evolving energy and producing carbon dioxide and water. When, however, this function is examined quantitatively, its maximum is seen to be reached in the animal. While the assimilative function characterizes the plant, the destructive function distinguishes the animal. Hence it is the function of the plant to store up energy to produce the highly complex protoplasm. This, consumed by the animal as his food, continues his existence as a living being, the energy gradually set free by its successive steps of retrogressive metamorphosis appearing as the work which he performs. If this view be correct, it would follow that every individual substance found in the animal—save only those which result from degradation—must be found in the plant upon which it feeds, and this is the fact. The myosine which Kühne has shown to be the distinctive proteid of muscle, Vines has found in the aleuron-grains of the lupine and the castor-oil plant, along with vitelline, the special proteid of the vitellus. The researches of Weyl and Bischoff have proved that gluten is formed in the dough of wheat-flour by the action of a ferment upon the globuline-substance or plant-myosine which it contains, precisely as Hammarsten has shown fibrine is produced in the action of a similar ferment upon fibrinogen. Not only this; Hoppe-Seyler has extracted from maize the identical substance which has been shown by Liebreich to be the essential chemical constituent of nerve-tissue, protagon.

The evidence, then, would seem conclusive that, since the protoplasm of the animal and the vegetable kingdoms is identical, the former in all cases being derived from the latter, the animal as such neither produces nor vitalizes any protoplasm. Two inferences seem naturally to follow from this conclusion: 1. That all the properties of animal protoplasm, and of the animal organism of which it constitutes the essential part, must have a previous existence in the plant; 2. That hence the solution of the life-question in the Myxomycetes will solve the life-problem for the highest vertebrate.

Another consideration which must not be left out of the account in any discussion of the life-question is the potent influence of environment. Ordinary examples of this influence pass before our eyes every day. Heat necessitates the germination of the seed, and light causes the plant to grow. Gravity obliges its root to grow downward and its stem to ascend. Certain sensations from without excite inevitably muscular contraction; and a ludicrous idea may provoke laughter in defiance of the will. Epidemic and epizoötic diseases show the dependence of function upon external conditions, and the germ theory demonstrates the utter disproportionality of the cause to the effect. The remarkable similarity in the periodicity observed between sunspots and the weather has been extended to include the appearance of locusts and the advent of the plague. Even the body politic feels its influence, Jevons having established a coincident periodicity for commercial crises.

The modern theory of energy, however, puts this influence in a still stronger light. As defined hitherto, energy is either motion or position; is kinetic or potential. Energy of position derives its value obviously from the fact that in virtue of attraction it may become energy of motion. But attraction implies action at a distance; and action at a distance implies that matter may act where it is not. This of course is impossible; and hence action at a distance, and with it attraction and potential energy, are disappearing from the language of science. But what conception is it which is taking its place? By what action does the sun hold our earth in its orbit? The answer is to be found in the properties of the ether which fills all space. The existence of this ether, the phenomena of light and electricity abundantly prove. While so tenuous that astronomy has been taxed to prove that it exerts an appreciable resistance upon the least of the celestial bodies, its elasticity is such that it transmits a compression with a wellnigh infinite velocity. On the one hand, Thomson has determined its inferior limit, and finds that a cubic mile of it would weigh only one thousand millionth of a pound; on the other, Herschel has calculated that, if an amount of it equal in weight to a cubic inch of air be inclosed in a cubic inch of space, its reaction outward would be upward of seventeen billions of pounds. Instead of being represented, as is our air, by the pressure of an homogeneous atmosphere

five miles in height, such a pressure would represent just such an homogeneous atmosphere five and a half billions of miles high, or about one third the distance to the nearest fixed star! In Herschel's own words, "Do what we will, adopt what hypothesis we please, there is no escape, in dealing with the phenomena of light, from these gigantic numbers, or from the conception of enormous physical force in perpetual exertion at every point throughout all the immensity of space."

Now, as Preston has suggested, if we regard this ether as a gas, defined by the kinetic theory that its molecules move in straight lines, but with an enormous length of free path, it is obvious that this ether may be clearly conceived of as the source of all the motions of ordinary matter. It is an enormous storehouse of energy, which is continually passing to and from ordinary matter, precisely as we know it to do in the case of radiant transmission. Before so simple a conception as this, both potential energy and action at a distance are easily given up. All energy is kinetic energy, the energy of motion. In a narrower sense, the energy of matter-motion is ordinary kinetic energy; the energy of ether-motion, which may become matter-motion, fills the conception of the older potential energy. Giving now to the ether its storehouse of tremendous power, and giving to it the ability to transfer this power to ordinary matter upon opportunity, and we have an environment compared with which the strongest steel is but the breath of the summer air. In presence of such an energy it is that we live and move; in the midst of such tremendous power do we act. Is it a wonder that out of such a reservoir the power by which we live should irresistibly rush into the organism and appear as the transmuted energy which we recognize in the phenomena of life? Truly, as Spinoza has put it, "Man thinks himself most free when he is most a slave."

Such, now, are some of the facts and fancies to be found in the science of to-day concerning the phenomena of life. Physiologically considered, life has no mysterious passages, no sacred precincts into which the unhallowed foot of Science may not enter. Research has steadily diminished day by day the phenomena supposed vital. Physiology is daily assuming more and more the character of an applied science. Every action performed by the living body is sooner or later to be pronounced chemical or physical. And when the last vestige of the vital principle shall disappear, the word "Life," if it remain at all, will remain to us only to signify, as a collective term, the sum of the phenomena exhibited by an active organized or organic being.

I can not close without speaking a single word in favor of a vigorous development in this country of physiological research. What has already been done among us has been well done. I have said with diffidence what I have said in this address, because I see around me those who have made these subjects the study of their lives, and who

are far more competent to discuss them than I am. But the laborers in the field are all too few, and the reasons therefor are not far to seek. One of these undoubtedly is the high scientific attainment necessary to a successful prosecution of this kind of investigation. The physiological student must be a physicist, a chemist, an anatomist, and a physiologist, all at once. Again, the course of instruction of those who might fairly be expected to enter upon this work, the medical students of the country, is directed toward making them practitioners rather than investigators. In the third place, the importance of physiological studies in connection with zoölogical research is only beginning in this country to receive the share of attention it deserves. I well remember the gratification I experienced in 1873 upon receiving a letter from Professor Louis Agassiz, asking me to give some lectures at Penikese upon physiological chemistry—a new departure for those times. In this view of the case it seems very appropriate that a new subsection of this Association should be just now in process of formation. We welcome warmly the body of men who form it, and we predict that from the new subsection of Anatomy and Physiology most valuable contributions will be received for our proceedings.

It is a beautiful conception of science which regards the energy which is manifested on the earth as having its origin in the sun. Pulsating awhile in the ether-molecules which fill the intervening space, this motion reaches our earth and communicates its tremor to the molecules of its matter. Instantly all starts into life. The winds move, the waters rise and fall, the lightnings flash, and the thunders roll, all as subdivisions of this received power. The muscle of the fleeing animal transforms it in escaping from the hunter who seeks to use it for the purpose of his destruction. The wave that runs along that tiny nerve-thread to apprise us of danger transmutes it, and the return pulse that removes us from its presence is a portion of it. The groan of the weary, the shriek of the tortured, the voiced agony of the babeless mother, all borrow their significance from the same source. The magnificence of the work of a Leonardo da Vinci or a Michael Angelo; the divine creations of a Beethoven or of a Mozart; the immortal "Principia" of a Newton, and the "Mécanique Céleste" of a Laplace—all had their existence at some point of time in oscillations of ether in the intersolar space. But all this energy is only a transitory possession. As the sunlight gilds the mountain-top and then glances off again into space, so this energy touches upon and beautifies our earth and then speeds on its way. What other worlds it reaches and vivifies we may never know. Beyond the veil of the seen, Science may not penetrate. But Religion, more hopeful, seeks there for the new heavens and the new earth, wherein shall be solved the problems of a higher life.

THE AUSTRALIAN ORNITHORHYNCHUS.

LIKE most other animals of Australia and the neighboring islands, the ornithorhynchus presents some strange peculiarities of structure and habit. Its body is flat, about eighteen inches long, its head and mouth are very much like those of the duck, and it has a short, broad, flat tail like that of a beaver. When young, the animal is

FIG. 1.—ORNITHORHYNCHUS PARADOXUS.

naked; the bill is short, and furnished with soft, fleshy borders, which enable the little ones to lay hold of the part on the body of the mother which affords the milk, but which is not pointed out by any teat. The tongue is large, and is likewise adapted to sucking. In the grown

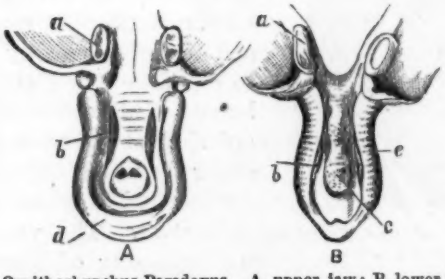


FIG. 2.—Jaws of the Ornithorhynchus Paradoxus. A, upper jaw; B, lower jaw; *a*, back tooth; *b*, flat front tooth; *c*, tongue; *d*, projecting skin; *e*, cross-grooves in the projecting skin.

animal the mouth is broadest in front, where it is rounded off; it is hard, and furnished with a porous skin which projects on both sides and runs around the front. Where this skin touches the forehead it

forms a broad fold which falls over the brow, and furnishes an excellent protection for the eyes when the animal is digging in the banks of the streams. The nostrils are close to the end of the upper jaw. In the lower jaw, or rather in the lower part of the mouth, are a number of elevations and depressions which run from the interior of the mouth outward through the protecting skin, and serve, like similar features in the duck, to let the water run out of the mouth when the animal is eating in the thin mud. Within the mouth is a pouch in the cheek, which is used as a place for preserving food. Four horny teeth are set in each jaw, of which the front ones are long and narrow, the others oval and hollow-crowned. The eyes are small and brown, set close down by the bill, and look upward. The ear is entirely hidden under the skin, yet the animal hears very well. The fore feet have five long toes, much alike, with thick, rounded claws; the toes are connected by a skin which extends over the claws when the animal is swimming, but is drawn back when it is digging. The skin of the hind foot reaches only to the base of the claws. The males when grown have also a movable, sharp spur on the hind foot. The milk-glands are in the lower part of the body, but are not marked by any teats; the glands swell out on sucking, and the projection thus formed is seized by the broad, soft mouth of the young. It was formerly thought that the ornithorhynchus laid eggs; but it is now known that it brings its young alive into the world from a double uterus through the so-called urogenital canal. The animal chooses its abode in quiet places on rivers and ponds, where the large-leaved water-plants afford it sure concealment, and the steep, muddy banks allow it to dig deep holes, often fifty feet in length. It is extremely shy, cautious, and alert, and generally swims around under the water, only raising its head for breath, but seldom high enough to be shot at. The young, born about the beginning of December, are put by the mother in a nest which she has prepared at the end of the burrow, and has lined with dry grass. They may be caught by digging them out. They do very well in an aquarium, and make comical, playful pets. The grown animals sleep through most of the day rolled up into a ball, but are lively at night. When free, they

FIG. 3.—A, fore foot of the Ornithorhynchus; B, hind foot; *a*, spur.

root for worms in the mud, or catch insects and small animals. They have a peculiar, fishy smell, and are eaten by the natives; but this is no sign that they are good, for the natives have no taste. They belong to the lowest group of the mammalia, the *Monotremata*, which includes the two genera *Ornithorhynchus* and *Echidna*; both these genera exhibit an arrangement of the breast- and shoulder-bones which is in a certain degree similar to that of the lizard and the extinct ichthyosaurus. In all the higher mammalia, the humerus is attached to the shoulder in a hollow of the scapula or shoulder-blade; in the ornithorhynchus, the hollow in which the ball of the humerus rests contains a bone connected with the shoulder-blade called the coracoid bone. The breast-bone in the mammalia consists of a broad

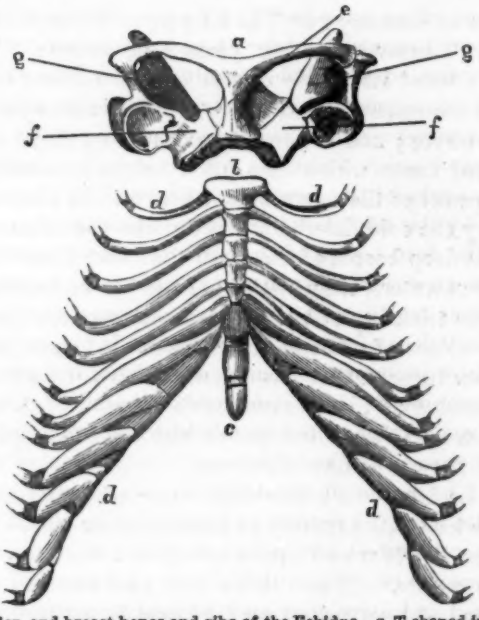


FIG. 4.—The shoulder- and breast-bones and ribs of the Echidna. *a*, T-shaped intermediate bone; *b*, manubrium; *c*, the sword-shaped end of the breast-bone; *d*, cartilaginous ribs; *e*, key-bone; *f*, the coracoid; *g*, the epicoracoid bone.

bone placed in front in quadrupeds, above the others in man, called the manubrium, and several smaller bones, which reach down to the belly, and have ribs on both sides; while in the other mammalia the manubrium is in contact with the neck-bone, in the ornithorhynchus the two coracoid bones are in contact with the manubrium. Some other bones are found on the breast and neck which are wanting in the other mammalia: first, a T-shaped bone which joins the breast-bone from below, and the cross of which bears at each end a neck-bone that reaches to the shoulder-blade; also, on each side in front of the coracoid bone, a so-called epicoracoid bone reaching to the neck. Some

of these bones are found occasionally in birds, reptiles, and amphibia. We meet a few other marks of the reptiles in the ornithorhynchus: for example, some ribs are partly or wholly separated from the spine; the hollow called the acetabulum, in which the thigh-bone is attached to the pelvis, is not perfect; the ear is formed very simply, the auditory canal not being wound spirally, and the outer ear being wanting.

THE MYSTERIOUS SOUNDS OF NATURE.

By ROBERT SPRINGER.

THE author of an essay on "The Empire of Tones," which was published at Brunswick a few years ago, wrote: "The globe is played upon around its whole circuit by the billows of the mighty ocean; it is encompassed by the strata of the atmosphere ever moving in sound-waves; and is swept from pole to pole by a flood of the most diversified tones which have their origin in nature. Over the eternal snow-peaks of the mountains, where all life has long since been made stark by the cold, howl icy storms like the voice of a gigantic organ. In the deep bosom of the earth the miner hears the murmur of the subterranean waters, the whistling of the jets of escaping gases, and the monotonous trickling of the gathered dampness. The human race has heard the voices of creation for thousands of years, from its childhood; but how incompetent has science been till now to explain the origin and meaning of these innumerable sounds!" A notice of some of the most remarkable of the sounds which are produced by the acoustic forces of nature will be of interest.

It should be borne in mind that waves of sound produced by a single impulse have the property of putting other waves in motion, so as to prolong the effect and produce a tone from the combination of the wave-movements. From this we may understand how resonances may be caused and harmonies may be heard in nature, the real origin of which may not be perceived by the common observer, or even by the learned investigator. Of such are the mysterious noises heard in the woods of Ceylon, on the banks of the Orinoco, and on the peninsula of Sinai. The rustle of the woods, the roll of the thunder, the crash of the storm, the murmur of the waterfall—all those sounds of the earth and the air of which the poets are so fond, and in which the ancients recognized the prophetic voices of the gods—sober science seeks to trace back to the same law whose operation is perceived when the bullet whizzes through the air, when the wind whistles through the crack of the door or window, when the burning wood snaps in the fireplace, when the stove-door crackles in cooling, when the teakettle sings that the water is boiling. Most of these sounds, which are pro-

duced by quickly succeeding impulses, approach in some degree to being musical tones. Water, in particular, has the property of giving forth sounds of this character, which vary in quality from the dull moaning of the waves to the charming warble of the gurgling brook and the pattering of the cascade. The great drops of the shower produce their melodies also, which in the cave of Staffa make a genuine water-music.

Among the natural sounds of obscure origin with which mythology and science have been occupied are the rustlings and so-called voices which seem to come from the air, sometimes from the bosom of the earth, and which have been remarked upon in all ages. Autenrieth refers them to the same class as the noises like thunder or the firing of cannon, which the hearers often fail to trace to an apparent cause. Sometimes they seem like the trampling of horses, or the roll of drums, or the clangor of trumpets ; at other times, like human voices. In the last case, the sounds are those which are common to all men, and may be interpreted by each hearer as in his own language. To the Romans they spoke Latin, to the Greeks Greek, to the Scotch Highlanders Gaelic. History has notices of these sounds ; the Bible descriptions attribute to them a religious significance. They are referred to when it is related that Samuel heard the voice of Jehovah three times in the temple ; when Habakkuk, pronouncing the curse on Babylon, spoke of the stones crying out in the walls ; when the glad voices of the mountains and waves are mentioned in the Psalms ; in the account in John of the voice that cried out from heaven when Jesus went into Jerusalem, and the people wondered whether it was thunder or an angel ; in the story of the conversion of St. Paul ; and in the account of the pouring out of the Holy Spirit on the day of Pentecost. The profane history of antiquity also tells of voices from above, and ascribes to them a supernatural significance and an influence over the hearts of men. Instances in point are the sounds of battle, and the clash of arms, and the neighing of horses, heard by night, according to Pausanias, on the field of Marathon ; the address of the god Pan to the Athenian ambassadors to Sparta, told of by Herodotus ; and the voices heard by both armies after the battle of the Romans with the sons of Tarquin. The Germans have myths of the din made by the war-god and his marching hosts, of the wild huntsmen, of strange cries and of the barking of dogs heard in the air ; and the French have stories not unlike them.

Accounts have been given in more recent times of air-noises of another kind, or "devil's music," which have been heard in the East, in Europe, and in America, and of which discussions may be found in the acoustic letters of Richard Pohl and in the "Musical Conversations-Lexicon" of Gathy. The devil's voice in Ceylon is heard in clear nights on the hills and among the valleys in different places, passing quickly from one spot to another, sometimes resembling the barking of a dog,

sometimes a mournful human voice, and has been described by several travelers, English, Dutch, and German. Autenrieth, Richard Pohl, Schubert, and others have endeavored to trace it to natural causes, but Schleiden gives up a satisfactory explanation of it. Persian traditions tell of a similar phenomenon, the cry of the Gule which is heard in the mountain-region of that country, together with the noises of the ringing of metals, the sound of drums, and the trampling of horses. The traveler Marco Polo, in the thirteenth century, told of noises of weapons and horsemen, the voices of men and musical harmonies which were heard frequently in the desert of Lob; and his contemporary, the monk Rubriquis, described the regions north of the Altai Mountains as the scene of similar manifestations. The devil's voice in Ceylon has been ascribed to the effects of excessive heat; these sounds of the more northern regions are possibly due to the dryness of the climate. The region of Mount Sinai is rich in curious harmonious sounds.

Unaccounted-for sounds have been accompanied in some of the hotter parts of Africa by a light, which may indicate an electrical origin; this has been noticed by several observers on a mountain near Cape Town. A manifestation, which may be called a sound mirage, was described in the "Magasin Pittoresque" in 1852 by an English writer, who related that while traveling in the desert at a time when the atmosphere was clear, and the heat glowing, and everything was quiet, he heard for about ten minutes a joyous sound like the ringing of church-bells. He suggested that the organs of hearing might have been set in vibration through the extreme dryness of the air. (Kinglake, in "Eöthen," relates a similar incident, if this is not the same.) The missionary Cabruta heard on the Orinoco a sound like the reverberations of cannon coming alternately from opposite directions, to which no one could assign an origin; and Humboldt says that the Indians of the same regions tell of the sound of the holy trumpets blown by the Great Spirit.

Similar phenomena have been noticed at different places in Europe, and people remote from each other have alike referred them to a supernatural origin. Among them were the sounds in the air heard by a priest at Aufacq, near Beauvais, of which an account is given in a manuscript of the last century, and the noise of the Arlecan which was heard in a churchyard near Arles. The Slavic peoples on the Adriatic and the Scandinavians of the North are equally inclined to believe in such manifestations and to notice them. The mirage of the *Fata Morgana* is sometimes accompanied with a sound like thunder. The Scottish Highlanders hear a mournful sound in the clefts of the rocks which they ascribe to an evil spirit. Arndt tells of soft tones and cries emanating from the mountains of the Orkney and Shetland Islands. Distinct cracking sounds are heard on the Adriatic Sea.

Echoes are frequently mentioned that repeat the sound six or seven times. Such an echo is said by Pliny to have been at a portico in Olympia; another echo, described by Gassendi, near the grave of Metella, repeated a verse of the "Æneid" eight times. Addison heard in Italy a pistol-shot echoed fifteen times. An echo in the county of Argyll repeats the sound eight times after equal pauses, but with diminishing force. These phenomena are favored by the neighborhood of rocks, caves, and bodies of water. Pierre de Castellane, a French officer who served in Algiers, relates that he heard an echo repeated a thousand times on the mountain-road to Bel-Abbes; it seemed to pass from one mountain to another, and to resound from side to side. Admiral Wrangell, in his work on Siberia, tells of an echo at Teheki, near Kirensk, on the Lena, where a pistol-shot is repeated more than a hundred times among the high rocks, and seems like a volley of musketry, but of the force of a cannon-shot.

Partly of the nature of the echo are the peculiar tones which are produced by the wind or the sea in rocky places. The learned Jesuit Kircher describes several such phenomena as sounding like the twanging of the harp, like an organ, or like bells. They have been noticed in Tartary, in Sweden, on the banks of the Guatemala Lake, and at a waterfall in the province of Kiang-si, China. Pausanias speaks of the tuneful waves of the Ægean Sea; Professor Bruder has perceived the chord of the third of C sharp in them. The experiments of the brothers Heim have made it probable that the resonant property resides in some quality of the waters; and Oersted has discussed the subject of the "Harmony of Waterfalls" in his work on the "Spirit of Nature."

The agency of echoes is also observed in the music of grottoes. A fearful sound has been said to be emitted from the grotto of Smaland near Wibourg, in Finland, as if a living animal were imprisoned there. Similar sounds are attributed to grottoes in Switzerland and the island of Hispaniola. A cave near Barable in Hungary gives out a noise like that of a pistol-shot. Harmonious, soothing tones prevail in other caves, as in Fingal's Cave, Staffa, where the falling water-drops, the breezes, and the rolling waves striking upon the basaltic columns, combine to make it a real cave of melodies. The accord of tones in this cave is no doubt attributable in a great degree to the symmetry of its shape, and the regularity of the form and arrangement of the basaltic columns. Other musical sounds proceed from the bosom of a rock called the Piedra de Carichana Vieja, on the banks of the Orinoco; they begin at sunrise, and are attributed to the action of changes of temperature. The musical sounds which are heard on the heights between Mount Sinai and the Gulf of Suez, the bell-tones of the Djebal Nakus rock in the Red Sea, and the noises like thunder in the region of Sinai which are mentioned by Burckhardt, are caused by the rolling of the sands among the rocks.

The sonorous property of rocks is also manifested in the phonoliths or ringing stones, of which several remarkable ones are known. The embassy of the East India Company to China found a rock near the city of Taucham, which gave out a noise like the sound of a trumpet whenever it was rubbed with the finger. Such stones are not uncommon in the department of the Loire, in France; and the basin of a fountain in the court of the Institute of France, in Paris, was observed by Elwart to give the chord of F sharp when struck by the hand.

Plants also afford their peculiar sounds and music. Of this nature were the oracular voices of the oaks at Dordona, a rustling of the trees around the temple of Zeus, which, with the accompanying murmur of the sacred fountain, was held to be prophetic. The rustling of the trees was regarded by the Scandinavians and the Celts as a language of nature, full of significance, of which the Druids were the consecrated interpreters. Possibly the woods, which the priests regarded as holy, had the property of producing real harmonies, like those of the Æolian harp. Such harmonious woods and musical trees are mentioned in many traditions of the olden time and reports of later times. Some soldiers, encamped in a valley in the Black Forest toward the end of the seventeenth century, heard charming sounds in the tops of the fir-trees, accompanied by the rustling of the wind as it blew through the narrow valley. A tradition of a similar music in a wood near Cithas, in the department of the Haute Saône, France, is confirmed by the testimony of an ear-witness, Désiré Monnier, author of "Traditions populaires comparées." The filao, a tree of the island of Bourbon, emits soft, melancholy tones when its slender boughs are shaken by the wind. An avenue of such trees is the source of wonderfully touching harmonies. The reeds and rushes of the island of Sylt, with their supple stems and interlaced roots, give forth, whenever the lightest wind is blowing, tones which are at times like whispers, like a subdued singing, or like a loud whistle. The wind, which in this case causes the root-fibers to be rubbed together and turns the limber stalks upon themselves, exerts a similar action on the innumerable thistles of the Hungarian steppes, where, as on the battle-field of Kapolna, mournful sounds, mingled with the soft soughing of the wind, are heard on still nights. The poets of all ages have sung of these sounds of nature; the literature of all nations abounds in fables and myths concerning them; they possibly suggested the first attempts to make musical instruments; and they have suggested to the great musical composers themes for many of the striking passages of their most successful works.—*Die Natur.*

THE ENGLISH PRECURSORS OF NEWTON.

II.

ROBERT HOOKE was born at Freshwater, in the Isle of Wight, July 18, 1635. Like Newton, he was a sickly child, and, like Newton too, his early years were distinguished and diverted by his singular mechanical ingenuity. He has left it on record that, having seen an old brass clock taken to pieces, he succeeded in constructing, in imitation of it, a wooden one that would, after a fashion, go; and about the same period he rigged out a miniature ship with ropes, pulleys, and masts, besides a contrivance to make it fire off some small guns while sailing across an adjacent haven; with what childish applause and self-gratulation, we are left to imagine. Nor did his sole gifts lie in this direction. His literary aptitude was beyond the common, and he showed a marked taste for music and painting. His education was as various as his talents. His father, who was minister of the parish, destined him for his own profession; but his infirm health precluded serious study, and it was consequently proposed to bind him apprentice to a watchmaker, or some similarly skilled artisan. After his father's death in 1648, his artistic tendencies so far got the upper hand, that we hear of him in the workshop of Sir Peter Lely, where, however, his occupation seems to have been nothing more æsthetic than color-grinding. Either this preliminary stage of art disgusted him, or (as his biographers prefer to state) the smell of oil-paint aggravated his constitutional headaches, and he was transferred to the care of Dr. Busby, the celebrated master of Westminster School, who kept him gratuitously in his own house for several years. Here his education, properly speaking, may be said to have begun. He not only acquired a competent knowledge of Latin and Greek, with a tincture of Hebrew and other Oriental languages, but is said to have astonished his teachers by mastering the first six books of Euclid in as many days, and by playing, without instruction, twenty lessons on the organ. In 1653 he entered Christ Church, Oxford, as servitor to a Mr. Goodman; and ten years later received, on the nomination of Lord Clarendon, then Chancellor of the University, the degree of Master of Arts, which his poverty had perhaps prevented him from taking in the ordinary course.

In 1654 the Hon. Robert Boyle, having finished his travels in Italy and his studies at Leyden, came to reside at Oxford. This amiable and ingenious gentleman has been quaintly panegyrized by an Irish humorist as "the father of chemistry and brother of the Earl of Cork." Although the clauses of this eulogy command different degrees of assent, and claim different kinds of esteem, they may be taken together as roughly summarizing the merits of its subject in the popular apprehension of that time. He was infected to an extraordinary extent with

the prevailing experimental fervor, and contributed perhaps more than any of his contemporaries to advance the credit and promote the cultivation of science. The tinge of credulity which occasionally colored his inquiries may be excused (in the words of Bacon's apology for corruption) as *vitium temporis non hominis*, and we suppress a smile at his solemn testamentary disposition of an infallible recipe for "multiplying gold," when we find Newton and Locke the eager recipients of the secret.

Several members of the "Philosophical or Invisible College" of London finding themselves about this time together at Oxford, their discussions were resumed, and Hooke's singular mechanical skill quickly brought him to their notice. Boyle at once attached him to himself, and, if we are to believe what Anthony Wood tells us,* was glad to improve his foreign acquirements by receiving from the young servitor instruction in Euclid, and some much-needed light on the Cartesian philosophy. What is more certain is, that Hooke constructed for him an air-pump vastly superior in design to that recently contrived at Magdeburg by Otto Guericke, and differing in no essential particular from that now in use. He further devised thirty different modes of flying, and emulated Archytas in the production of a "Module" (we quote his own words), "which, by the help of springs and wings, raised and sustained itself in the air; but finding," he adds, "by my own trials, and afterward by calculation, that the muscles of a man's body were not sufficient to do anything considerable of that kind, I applied my mind to contrive a way to make artificial muscles, divers designs whereof I shewed also at the same time to Dr. Wilkins, then Warden of Wadham College, but was in many of my trials frustrated of my expectations." †

It may be conjectured that the failure of these attempts sufficed to convince the Icarus of Wadham of the impracticability of his projected lunar excursion, as well as to divert their author to less ambitious designs. The improvement of timepieces was then looked upon as the shortest road to the solution of the great practical problem of finding the longitude at sea, and in this direction, accordingly, Hooke next turned his thoughts and his experiments. He was rewarded by the discovery of a contrivance for applying springs to regulate the movement of watches. For this important invention his friends endeavored to procure him a patent, which he, however, refused, being dissatisfied with the terms proposed; and it thus remained undivulged, and by many disbelieved in. But when, in 1675, Huygens published, in the "Journal des Savants," his discovery of spiral watch-springs, Hooke indignantly claimed it as his own, incidentally attacking Oldenburg, then Secretary of the Royal Society, with whom he was never on very civil terms. A sharp paper-conflict ensued, Hooke (quite unjustifiably)

* "Athenæ Oxonienses," vol. iv., p. 628.

† "The Life of Dr. Robert Hooke," "Posthumous Works," p. iv.

accusing Oldenburg of "trafficking in intelligence," and Oldenburg retaliating with the better-founded assertion that Hooke's "pendulum-watches" could never be got to go; while Huygens, who might well disdain to wrangle over so small a prize, stood aloof, and let the controversy rage. Hooke's priority, as regards the principle, is unquestionable; but it is equally unquestionable that the modification introduced by Huygens first brought the improved timepieces into general use. That modification was nothing more than the coiling into a spiral of a spring which, in Hooke's design, had remained straight. So fine is the line drawn between failure and success.

The history of this invention is, in brief, the history of Hooke's life. He was a man whose brilliant qualities were neutralized one by the other. His extraordinary ingenuity was marred by his equally extraordinary versatility. His thoughts pursued each other in a rapid succession of vivid and original suggestions; but they found no halting-place on the way. He received them with rapture, but they wearied him if they staid too long. He welcomed all, but made none his friend. He wanted that laborious passion of perfection, apart from which the progeny of invention is but a sterile brood. His mind was like a telescope without clock-work, which shows the moving host of heaven, but can not fix or observe any individual star. Thus, his discoveries and investigations were usually abandoned or postponed when on the point of completion. It was not until some other inquirer, less discursive or more discreet, added the finishing touches still wanting, that he became sensible of the full value of what he had neglected, and, with loud vociferations, stood on the highway of learning, crying "Stop thief!" to the whole scientific world. Nor was his manner of conducting these controversies happier than his choice of occasions for them. His tone in argument was at all times dictatorial, and under excitement it was apt to become shrill. By his arrogance, he exasperated his adversaries; by his irritability, he prejudiced his cause. Thus, when (as not unfrequently happened) he was in the right, he roused animosity; when he was in the wrong, he incurred discredit.

But we anticipate our narrative. The foundation of the Royal Society opened to him the road to fortune and fame. Having raised his reputation by an able paper on "Capillary Attraction," his name was placed on the first list of Fellows, and on November 12, 1662, he was unanimously elected Curator of Experiments, "with the thanks of the Society ordered to Mr. Boyle for dispensing with him for their use." He had at this time entered on his twenty-ninth year, and had within him a spirit of fire, not indeed "grossly," but most inadequately "clad" in the corporeal "dimension" of his species. Pepys, who knew him well and rated him high, notes in his "Diary" that "Mr. Hooke is the most, and promises the least, of any man in the world that ever I saw." His personal appearance, indeed, was to the last degree deplorable. His figure was crooked, his limbs shrunken and emaciated, his aspect

meager, his carriage stooping. He wore his hair, which was of a dark-brown color, hanging in long, disheveled locks over his face, and it was not until three years before his death that, conforming at last to the fashion of his time, he cut it off, and substituted a periwig. Up to the age of sixteen, he was said to have been straight, and he himself attributed his deformity to his excessive use when young of "incurvating exercises," such as working with a turning-lathe. Waller, his earliest biographer, tells us:

> His eyes were gray and full, with a sharp ingenious look while younger; his nose thin, but of a moderate height and length; his mouth meanly wide, and upper lip thin; his chin sharp and forehead large; his head of a middle size. . . . He went stooping and very fast, having but a light body to carry, and a great deal of spirits and activity, especially in his youth. He was of an active, restless, indefatigable genius even almost to the last, and always slept little to his death, seldom going to sleep till two, three, or four o'clock in the morning, and seldomer to bed, oftener continuing his studies all night, and taking a short nap in the day. His temper was melancholy, mistrustful, and jealous, which more increased upon him with his years. . . . He had a piercing judgment into the dispositions of others, and would sometimes give shrewd guesses and smart characters.*

The extreme parsimony, which the necessities of his early life had rendered a virtue, degenerated, as years went on, into a weakness if not into a vice. After his death, a large iron chest, which it appeared by evident signs had lain undisturbed for above thirty years, was discovered in his lodgings, and on being opened was found to contain several thousand pounds in gold and silver, accumulated by him in the lucrative employment of surveyor for the rebuilding of the city after the fire of September 3, 1666. Thus he condemned himself to a life of sordid privation, while relegating to dust and cobwebs a treasure which he was too penurious to spend, and too busy even to enjoy the miser's pleasure of counting.

It is difficult to convey an adequate idea of the multifarious and unceasing activity of Hooke's intellectual life during the forty years of his connection with the Royal Society. It reflected the boundless but fortuitous curiosity of an age which had indeed realized the bold vaunt of its heraid, by leaving the pillars of Hercules of ancient lore far behind; but now found itself, like Ulysses of old, embarked on a trackless ocean without any sure pilotage to the happy isles of renovated science. Hooke and his contemporaries were inflamed with the unmeasured hopes and vast ambition of the Verulamian prophecies; but they began to be more and more conscious that the Verulamian method was but as the "golden path of rays" leading to the setting sun. They were haunted by the idea that Nature was to be interrogated, not progressively or by installments, but once for all, by a supreme inductive effort,† and they could not wholly relinquish the hope that they were destined to witness its consummation. They had been

* "Life," p. xxvii. † Bacon, preface to the "Parasceve," "Works," vol. i., p. 394.

told to expand their souls to the measure of the universe, and they were unwilling to confess their inadequacy to the effort required of them. They were like men groping in the darkness for a door which they had but to throw wide, in order to find themselves in the full blaze of daylight; and they learned with reluctance that only by painful and prolonged exertions could they expect to open a chink here and there for a ray of twilight to enter.

This insensible change of front, as regards scientific method, is very clearly discernible in Hooke's writings. He began life with hopes as large as and more defined than those of Bacon himself. Even before he left Oxford, he had provided himself with what he called a "mechanical algebra," which he regarded as an infallible guide to invention. This he afterward expanded into an elaborate engine of discovery, competent, as he believed, to construct with certainty and swiftness an edifice of knowledge, heretofore unmatched for vastness and durability. The scheme, like all his more ambitious designs, remained incomplete, or, at most, was completed only in the mind of its author; and the tract in which he describes it breaks off just as the momentous secret is about to be disclosed. Whether it was that the difficulties in the way became more clear to him as he advanced, and that he lost faith in his own means of removing them, or whether it was that his jealousy of disclosure overbalanced, at the critical moment, his appetite for fame, we shall never know. We do know, however, enough to show us that the revelation would have been valuable only as a gratification of our curiosity, and as throwing a singular light on the visions which haunted the morning of experimental science.

The following extract from his essay on "The Present State of Natural Philosophy" briefly exposes his ideal of a method. He attempted, as will be seen, to come to closer quarters with the problem than Bacon had done, and succeeded thereby in more clearly defining its insolubility.

"Some other kind of art for inquiry," he writes,* "than what hath been hitherto made use of, must be discovered; the intellect is not to be suffered to act without its helps, but is continually to be assisted by some method or engine, which shall be as a guide to regulate its actions, so as that it shall not be able to act amiss. Of this engine, no man except the incomparable Verulam hath had any thoughts, and he indeed hath promoted it to a very good pitch; but there is yet somewhat more to be added, which he seemed to want time to complete. By this, as by that art of Algebra in Geometry, 'twill be very easy to proceed in any natural inquiry, regularly and certainly: and indeed it may not improperly be called a Philosophical Algebra, or an art of directing the mind in the search after philosophical truths."

The first part only of this "Algebra of Discovery," "containing the manner of preparing the mind, and furnishing it with fit materials to work on," was written; the second, which should have set forth "the

* "Posthumous Works," p. 6.

rules and methods of proceeding and operating with this so collected and qualified Supellex," remained in embryo. Hooke, like Bacon, set out with a classification of the errors incidental to humanity in its actual condition; but his mode of rectifying them was a more patient and practical process than the "expurgation of the intellect," preached by the philosophic Chancellor. The senses are to be helped, he tells us, by skillfully constructed instruments, whereby their sphere of action may be enlarged, and their untutored impressions brought to the test of exact measurement and rigid calculation. The report of one sense must be corrected by comparison with that of the others, until "sensation is reduced to a standard," and the mind is gradually informed with true notions of "things, as they are part of, and actors or patients in the universe, not only as they have this or that peculiar relation or influence on our own senses or selves."

The next step in the "Preparation" consisted in the compilation of a "Philosophical History," comprising—

> A brief and plain account of a great store of choice and significant natural and artificial operations, actions, and effects, ranged in a convenient order, and interwoven here and there with some short hints of accidental remarks or theories, of corresponding or disagreeing received opinions, of doubts and queries, and the like; and, indeed, until this repository be pretty well stored with choice and sound materials, the work of raising new axioms or theories is not to be attempted, lest beginning without materials the whole design be given over in the middle.*

The matter of such a history, he says further, is no less than the world; "for there is no body or operation in the universe that is not some way or other to be taken notice of in this great work." And the programme which he proceeds to lay down in no way belies his promise. Fire, air, earth, and water, light and darkness, heat and cold, gravity and levity, all the "prime sensible qualities" of nature, find each its place in this stupendous magazine of knowledge. From ether to anthracite, from a man to a mite or a mushroom, from dreams and influences to arts and sciences, from the starry firmament to the costermonger's cart or the cobbler's stall, no substance, quality, or accident is excluded. No natural process, no commercial product, but has its separate "History." The despised handicraftsman is to yield up his obscure secrets as well as the scientific artisan. A Dollond or a Steinheil is not more stimulating to the catholic curiosity of the natural historian than a Quince, a Bottom, or a Snug. Yet all this encyclopedic mass of information, infinite in its subject, indefinite in its extent, expansive in its nature, Hooke tells us he "has very good reason to believe may be contained in much fewer words than the writings of divers single authors!"† This would, indeed, have been to imprison the liberated genius of knowledge within narrower limits than those

* "Posthumous Works," p. 18. † Ibid., p. 21.

of Aristotelian tradition. The seal, however, was broken; the vase was already at the bottom of the sea, and it only remained to guide and propitiate a power which it was no longer possible to confine.

The "Philosophical History," of which Hooke traced the gigantic plan, would, in fact, have included what we now understand as the whole body of inductive science, with a considerable margin of heterogeneous material, difficult of classification, and more curious, perhaps, than useful. It would have included not only an enumeration of all possible phenomena, but the knowledge of the laws by which they are governed, and the causes by which they are produced. The natural historian was to be "knowing in hypotheses," that he might set his facts in plausible sequence of cause and effect; he was to be a skilled mechanician, and an able mathematician, that he might investigate their relations by experiment, and deduce the consequences of such relations by calculation. Hooke's "Helps of Discovery" are but another form of Bacon's "Prerogative Instances"; but it is significant that in the later system they appear in the preparatory stage, while in the earlier they form an integral part of the "Organum" itself. The impossible was, in fact, relegated to a distant future, while the possible took possession of the present. The "raising of axioms," and the discovery of "forms," which were supposed to constitute the true business of the philosopher, were postponed in favor of the more modest task of setting facts in order, and connecting them by means of ideas. Thus natural philosophy, in the recondite sense in which it was understood by the theorists of the seventeenth century, came, as time went on, to be more and more fully personated by her handmaiden, "Natural History," until at last the identity of the one was completely merged in that of the other. The intermediary whom they had admitted as a messenger of higher promise, they were compelled to take for better for worse. Like Malvolio, they had wooed the mistress; like Sir Toby, they wedded the maid.

We shall conclude our remarks on this singular essay by transcribing some specimens of the queries directed by Hooke to future investigators. Even after the lapse of above two centuries, they strike us as suggestive and ingenious. Under the heading of "Ether," he asks:

> Whether it permeates all bodies, be the medium of light, be the fluid body in which the air is but as a tincture? Whether it cause gravity, in the earth or other celestial bodies?

Of the atmosphere:

> Whether it encompasses the sun and planets, and that each of them have a peculiar atmosphere, as well as they have a gravitating power?
>
> Whether the spots in the sun may not be clouds of smoke or vapors, raised up into that atmosphere?
>
> Whether meteors have anything of fire in them, or whether the light may not be an effect of their rapid motion?

Although Hooke's "True Method" was not published until after his death, we may safely attribute it to an early stage of his career. He was a man whose ideas did not change, but were superseded. They retained their original form, but were crowded out of sight by the multitude of new arrivals. Now we have evidence to show that, without wholly abandoning his early faith in the efficacy of his "Philosophical Algebra," his confidence in an approaching renovation of science was replaced, later in life, by a conviction of its infinite complexity and extent. In the preface to a volume of "Lectures," published in 1674, he says:*

> For as there is scarce one subject of millions that may be pitched upon, but to write an exact and complete history thereof would require the whole time and attention of a man's life, and some thousands of inventions and observations to accomplish it: so on the other side no man is able to say that he will complete this or that inquiry, whatever it be (the greatest part of invention being but a lucky hit of chance, for the most part not in our own power). 'Twill be much better, therefore, to embrace the influences of Providence, and to be diligent in the inquiry of everything we meet with. For we shall quickly find that the number of considerable observations and inventions this way collected will a hundredfold outstrip those that are found by design. No man but hath some lucky hits and useful thoughts on this or that subject he is conversant about, the regarding and communicating of which might be a means to other persons highly to improve them. . . . This way is also more grateful both to the writer and the reader, who proceed with a fresh stomach upon variety, but would be weary and dull'd if necessitated to dwell too long upon one subject.†

Thus we see that discovery, which speculation had proclaimed to be the infallible result of system, was by experience declared to be the lucky outcome of chance. Investigators had previously been commanded to march in a compact army along the highway of method toward the metropolis of knowledge; they were now warned to disperse in all possible directions into the wilderness of phenomena, and beat the bushes of nature for what game they might contain. That one view was equally misleading with the other is obvious; that one should form the reaction from the other was inevitable. Hooke's reasons for discursiveness were not so much the guide of his conduct as its apology. His position as Curator of Experiments to a body inordinately greedy of scientific novelty suggested a wide range of subjects for inquiry, which his native versatility induced him to embrace to its fullest extent. The journals and registers of the Royal Society alone convey, by their records, an adequate idea of his prodigious activity of mind, fertility of resource, and experimental skill. Astronomy, optics, acoustics, thermotics, pneumatics, hydrostatics, magnetism, and chemistry; geology, physiology, meteorology, and psychology—all in turn engaged his attention, and all in turn received illustrations from

* "Posthumous Works," p. 29.

† "An Attempt to prove the Motion of the Earth," London, 1674.

his sagacity, and impulses from his zeal. Of all men who ever lived, he was perhaps the most prolific in mechanical invention. New instruments, or useful modifications of those already in use, flowed from him by the dozen. An arithmetical machine, a triple writing-machine, a deep-sea sounding machine, a wind-gauge, rain-gauge, hygrometer and odometer, a system of telescopic telegraphy, a "water-poise," a "weather-clock," and a species of microphone, were all due to his ingenuity; besides important improvements in astronomical and other instruments —telescopes, quadrants, micrometers, diving-bells, barometers, thermometers, and balances. He speculated curiously on memory, and calculated the number of ideas of which the human mind is susceptible, estimating it at three thousand one hundred and fifty-five million seven hundred and sixty thousand! He constructed a model for the rebuilding of London after the great fire, which was approved, although not adopted; and was the architect of Hoxton Hospital and other buildings. He read before the Royal Society commentaries on Ovid's "Metamorphoses," Plato's "Atlantis," and Hanno's "Periplus," interpolating these critical excursions between geological theories and astronomical observations. To him was due the ingenious idea of measuring the force of gravity at different altitudes by the rate of vibration of a pendulum of a given length; as well as the determination (so far as the actual state of chemical knowledge permitted it to be determined) of the true function of the air in combustion and respiration. His zeal carried him to the length of making, in an exhausted receiver, his own person the subject of his observations—"the only experiment of that kind," his biographer naïvely remarks, "I think ever tried."

At the present time, when weather prophecies have come to form a recognized part of our complex social machinery, it would be ungrateful to omit noticing that Hooke was the first to propose a scientific system of meteorological forecasting. His scheme, as might be expected, had for its basis the close association (remarked by him among the earliest) of changes of weather with barometrical variations; which, he writes to Boyle, October 6, 1664—

> If it continue to do as I have hitherto observed it, I hope it will help us one step toward the raising a theorical pillar or pyramid, from the top of which, when raised and ascended, we may be able to see the mutations of the weather at some distance, before they approach us; and thereby being able to predict and forewarn, many dangers may be prevented, and the good of mankind very much promoted.*

The means recommended by him for the furtherance of this noteworthy object were the same in principle as those now in use at all the meteorological observatories of Europe and America. Two hundred years, however, had to elapse before they could be profitably employed.

* Boyle's "Works," vol. vi., p. 492.

In his "Method for making a History of the Weather," * the attention of observers is especially directed to the following "particulars," as "requisite for the raising of axioms whereby the cause or laws of weather may be found out": 1. The strength and quarter of the winds. 2. The degrees of heat and cold. 3. The degrees of dryness and moisture observed with a hygroscope "made with the single beard of a wild oat perfectly ripe, set upright and headed with an index." 4. The degrees of pressure of the air. 5. The constitution and face of the sky.

It is perhaps worth remarking that our present system of meteorological observations corresponds with tolerable accuracy to Bacon's notion of how a "history" of any special branch of physics should be compiled; with this difference in result, that, instead of arriving at "axioms" and "forms," we have as yet obtained only a set of empirical rules which, however practically useful, can scarcely be said to constitute a science.

"Discoursed with Mr. Hooke," Pepys wrote, August 8, 1666, "about the nature of sounds, and he did make me understand the nature of musicall sounds made by strings, mighty prettily; and told me that having come to a certain number of vibrations proper to make any tone, he is able to tell how many strokes a fly makes with her wings (those flies that hum in their flying) by the note that it answers to in musique, during their flying. That, I suppose, is a little too much refined, but his discourse in general of sound was mighty fine." †

Notwithstanding Mr. Pepys's skepticism, Hooke was on this occasion not "refining" overmuch. He exhibited in 1681 an instrument (with the principle of which he had doubtless long been acquainted) for counting the pulsations of sound, which seems to have been virtually identical with that now known as "Savart's Wheel." He also anticipated Chladni's celebrated experiment by strewing flour on a vibrating glass bell, thus presenting to the eye, as it were, a picture of the configuration of rest and motion on its surface. It was one of his favorite ideas that, by some future discovery, the sense of hearing would be reënforced as prodigiously as the sense of sight had already been by the telescope—an intuition singularly realized by the recent invention of the telephone. "It has not yet been thoroughly examined," he wrote in 1664,‡ "how far Otocousticons may be improved, nor what other ways there may be of quickening our hearing, or conveying sound through other bodies than the air." "By very casual trials," he tells us elsewhere, he had made some progress in this direction, and was by no means convinced that they might not be prosecuted so far as to render audible noises made at the distance of the planets! Although acknowledging that to his own prejudices this seemed "a very extravagant conjecture, . . . yet methinks," he adds, "I should have

* Published by Sprat, "History of the Royal Society," p. 173.

† Pepys's "Diary," vol. iv., p. 43, Bright's edition. ‡ "Micrographia," preface.

had the same thoughts of a conjecture to find out a help for the eye to see the smaller parts and rocks of the moon," and "would fain persuade myself against concluding or building on the impossibility of such things as I am not able demonstrably to prove not possible."*

Of Hooke's private and personal history there is little to be recorded. His life might almost be comprised in two words—experiments and controversies. In 1664 Sir John Cutler instituted, especially for his benefit, a mechanical lecturership of fifty pounds a year; in the following year he was appointed to the professorship of Geometry† founded by Sir Thomas Gresham in 1575. His services as curator were remunerated by an annual stipend of thirty pounds, not perhaps very regularly paid, since we hear, on one occasion, that both he and Halley were offered, in lieu of their respective salaries, an equivalent number of copies of that unlucky "History of Fishes," by the publication of which the Royal Society had drained their finances and cumbered their shelves. The famous controversy between Hooke and Hevelius on the subject of plain or telescopic sights, which agitated the learned world of Europe during many years, has long ago sunk into a silence we need not disturb. Hevelius was in the wrong, and obstinate; Hooke was in the right, but offensive. Astronomers in general seemed disposed to prefer some slight uncertainty as to the position of the stars, to being bullied into precision by the magisterial little hunchback of Gresham College. The dispute remained long in the condition of a smoldering flame, with outbreaks of argument at distant intervals, and Halley's mission of conciliation in 1679 helped to soothe the vanity of the irritated philosopher of Dantzic, but did not tend to rectify his method.

We now come to the relations of Hooke with Newton. The first collision between these two remarkable men occurred on the subject of their respective optical discoveries. Hooke's merits in this direction were very considerable. He was the first to propound that view as to the nature of light now universally accepted under the name of the "undulatory theory." He held that light is a "very short vibrative motion," originating in an agitation of the minute particles of the luminous body, and propagated through a perfectly homogeneous and elastic medium "by direct or straight lines, extended every way, like rays from the center of a sphere, . . . just after the same manner (though indefinitely swifter) as the waves or rings on the surface of the water do swell into bigger and bigger circles about a point of it, where by the sinking of a stone the motion was begun."‡

Further, he hit upon the principle of "interference," which, neg-

* "Of the True Method of building a Solid Philosophy," "Posthumous Works," p. 39.

† Hooke read the "Gresham Lectures on Astronomy" in 1664–'65, during the absence in Italy of Professor Pope; but never occupied that chair except as *locum tenens*.

‡ "Micrographia," pp. 56, 57.

lected by Huygens and ignored by Newton, was destined, in the hands of Young and Fresnel, to afford demonstrative proof of the truth of the hypothesis roughly sketched by Hooke. In his "Micrographia" (justly styled by Pepys "a most excellent piece") he described, besides a series of beautiful observations with the microscope, the phenomenon known in optical treatises as the "colors of thin plates," and with singular sagacity declared it to form the *experimentum crucis* as regards chromatic light. These "fantastical" tints (which we may recognize every summer's day in the iridescent glancing of some insect's wing) Hooke diligently examined in soap-bubbles, in "muscovy-glass" (mica), in metallic films, and other similar substances. His explanation of what he observed contains a remarkable, although necessarily imperfect, approximation to a cardinal truth in optics. By a double reflection from two closely adjacent surfaces, he tells us,* the rays of light are broken up into "confused or duplicated pulses," changing in tint with the varying thickness of the reflecting film. Thus, "colors begin to appear, when the pulses of light are blended so well and so near together that the sense takes them for one."† According to the modern doctrine of "interference," waves of light, pursuing each other at the distance of half an undulation, mutually destroy each other, and produce darkness. But, because difference of color means difference of wave-length, a doubly-reflecting surface, by destroying or reënforcing, according to its varying thickness, undulations of certain lengths, analyzes white light into the prismatic rays of which it is composed, and thus produces the appearances characteristic of "thin plates."

The flaw in Hooke's theory was his erroneous idea as to the nature of color. And on this point we are unable to defend him from the charge of culpable ignorance. The true view was proposed to him, and he deliberately rejected it. The keystone of the arch he had attempted to build was offered to him, and he declined to set it in its place. On February 8, 1672, Newton's memorable paper on the composition of white light was read before the Royal Society. Had Hooke frankly accepted the discovery, and applied it as a bulwark to his own tottering hypothesis, his name would doubtless have sounded louder in the ears of posterity. But here his moral failings, as well as his intellectual shortcomings, interposed. He was, primarily, an experimentalist. His delight was rather in the things than in the thoughts of Nature. The intimate relations of objects were of less account in his eyes than their external operation on the senses. Add to this the utilitarian tendency impressed upon physical researches by the Baconian precepts. In the preface to the "Micrographia" Hooke described as follows the purposes of the Royal Society: "They do not wholly reject experiments of mere light and theory, but they principally aim at such, whose application will improve and facilitate the present way of manual arts." And similar declarations were made by Boyle and

* "Micrographia," p. 66. † "Posthumous Works," p. 190.

other leading men of the time. Thus, in Hooke's apprehension, the *raison d'être* of an hypothesis was not so much to suggest a physical connection of facts as to provide a convenient classification of experiments, and its most essential quality that it should be plausible, not that it should be true.

His judgment was besides warped, even more than that of most men, by that intellectual egotism which, if it sometimes acts as a spur to progress, more often performs the office of a drag. His self-love blinded him to the real merits of his competitors. His own speculations loomed so large before him as to exclude from his field of view those of every other. Newton acknowledged that, if he saw farther than most men, it was "by standing on the shoulders of giants." Hooke thought his own mental stature sufficient to entitle him to reject such extraneous aids. He accordingly set aside without hesitation Newton's discovery, offering his criticisms, not indeed discourteously, but with a certain air of superiority which not a little galled his sensitive antagonist. Matters were aggravated three years later when Newton published his beautiful explanation, on the emission hypothesis, of the colors of thin plates. Hooke declared that "the main of it was contained in the 'Micrographia,'" a remark extremely offensive to Newton, who, however, with his usual careful justice, immediately extended his somewhat scanty acknowledgment of his rival's labors, by defining with scrupulous accuracy the measure in which he was indebted to him. That Hooke was not devoid of generous sentiments appears from a letter which he wrote about this time to Newton, proposing a private correspondence on philosophical subjects.* In it he acknowledges the superior abilities of the great mathematician, professes a dislike to contention, and hints that their relations had been embittered by the machinations of ill-disposed persons. (Oldenburg is evidently indicated.) Newton's reply was conceived in a corresponding spirit; but the harmony thus established was unhappily not lasting.

The problem of gravity was the supreme question of that time. It stood first among the orders of the day of the scientific council. It was instinctively felt that, until it should be disposed of, no real progress could be made in physical knowledge. And, slowly but surely, the way was being prepared for a great discovery. Galileo had made Newton possible. Men's ideas were gradually clarifying; the great cosmical analogies, now so familiar, were step by step emerging out of the dusk of ignorance; antiquated prepossessions were sinking, in a sediment of cloudy cavil, out of sight. Heaven was assimilated to earth, and earth to heaven; the old gratuitous separation between the starry firmament over our heads and the solid globe under our feet was abolished by acclamation, and it was felt that the coming law, to be valid, must embrace in its operation the whole of the visible uni-

* Brewster, "Life of Newton," vol. i., p. 138.

verse. Toward this consummation Gilbert contributed something by his theory of universal magnetism; and Galileo, as well as Bacon and Horrocks, foresaw that in this direction lay the coveted secret. In 1645 the Abbé Boulliau (Bullialdus) actually announced* that the force by which the sun holds the planets in their orbits must vary as the inverse square of their distance from him; in 1666 Borelli published at Florence some suggestive speculations on the subject;† in England, Wallis, Wren, and Halley, all eagerly scanned the question, and all arrived at close approximations to the truth. But it was undoubtedly Hooke whose arrow flew nearest to the mark. The first definite proposal of the planetary revolutions as a problem in mechanics is due to him; and it has been immemorially held that *prudens quæstio est dimidium scientiæ*. In a paper on "Gravity," presented by him to the Royal Society, March 21, 1666, the following noteworthy passage occurs:

> If such a principle (central attraction) be supposed, all the phenomena of the planets seem possible to be explained by the common principle of mechanic motions; and possibly the prosecuting this speculation may give us a true hypothesis of their motion, and, from some few observations, their motions may be so far brought to a certainty that we may be able to calculate them to the greatest exactness and certainty that can be desired.‡

On this matter, at least, Hooke's ideas were persistent and progressive. In 1674 he announced a forthcoming "system of the world, answering in all things to the common rules of mechanical motions," and founded on the three following suppositions:

> 1. That all celestial bodies whatsoever have an attraction or gravitating power towards their own centres, whereby they attract not only their own parts . . . but also all the other celestial bodies that are within the sphere of their activity. 2. That all bodies whatsoever that are put into a direct and simple motion, will so continue to move forward in a straight line till they are, by some other effectual powers, deflected and sent into a motion describing a circle, ellipsis, or some other more compounded curve line. 3. That these attractive powers are so much the more powerful in operating by how much the nearer the body wrought upon is to their own centres. Now, what these several degrees are, I have not yet experimentally verified, but it is a notion which, if fully prosecuted, as it ought to be, will mightily assist the astronomer to reduce all the celestial motions to a certain rule, which I doubt will never be done without it. But this I durst promise the undertaker, that he will find all the great motions of the world to be influenced by this principle, and that the true understanding thereof will be the true perfection of astronomy.§

Our readers will perceive that he was at this time still at fault as to the rate of decrease of the central force; but, some years later, this

* "Astronomia Philolaica," Paris, 1645.

† "Theoricæ Mediceorum Planetarum," Florence, 1666.

‡ Birch, "The History of the Royal Society," vol. ii., p. 91.

§ "An Attempt to prove the Motion of the Earth," p. 28.

too was divined by him—divined, not demonstrated. In 1679 he wrote to Newton, suggesting the law of inverse squares, or "reciprocal duplicate proportion," and it was this letter which led the Cambridge philosopher to "resume his former thoughts concerning the moon."* He first, as is well known, attempted the problem of assimilating the force of gravity at the earth's surface to the deflecting power exerted on the moon's orbital motion, in 1665, when he "gathered" the duplicate proportion from Kepler's third law; but the defective *data* then at his command obliged him to suspend his speculations. Now, with the results of Picard's improved degree measurement in his hands, he once more set his gigantic powers to their equally gigantic task. Having made some progress with the calculations, he, however, again "threw them by, being upon other studies"†; and it required a further fillip to induce him to complete them. It was given thus:

One January day in 1684, Edmund Halley, a young and rising astronomer, having independently worked out the great problem so far as to perceive the necessity for the ratio of inverse squares, came to town from Islington, and, falling into discourse with Wren and Hooke on the subject, the latter "affirmed that upon that principle all the laws of the celestial motions were to be demonstrated, and that he himself had done it. I declared," continues Halley,‡ "the ill-success of my attempts, and Sir Christopher, to encourage the enquiry, said that he would give Mr. Hooke some two months' time to bring him a convincing demonstration thereof, and besides the honour, he of us that did it should have from him a present of a book of forty shillings. Mr. Hooke then said he had it, but should conceal it for some time, that others trying and failing might know how to value it when he should make it public. However, I remember that Sir Christopher was little satisfied that he could do it, and though Mr. Hooke then promised to show it him, I do not find that in that particular he has been so good as his word."

The two months' interval allowed by Wren for the production of the desired solution elapsed four times over, and Hooke made no sign. Then, at last, Halley started for Cambridge, and laid the difficulty before Newton. In after-life he was accustomed to boast that "he had been the Ulysses who produced this Achilles."§ For the result of his visit was the "Principia."

The most painful passage in Hooke's life now comes before us. When the first book of his rival's immortal work was, on April 28, 1686, received by the Royal Society with the applause which it deserved, he was unable to restrain his jealous disappointment within the bounds of moderation or decency. He quarreled with the Presi-

* Brewster, "Life of Newton," vol. i., p. 291.

† Letter to Halley, quoted by Brewster, vol. i., p. 292.

‡ Letter to Newton, quoted by Brewster, vol. i., p. 293, note.

§ Brewster, "Life of Newton," vol. i., p. 298.

dent for overlooking his prior claims; he endeavored to persuade the members that Newton was indebted to him for the first hint of a discovery which he pretended was but a small part of what he himself had conceived, and was engaged in perfecting; he did not attempt to conceal that he regarded Newton's triumph in the light of a personal injury. When this "strange carriage" was reported (probably with some exaggeration) to Newton, he was, not unreasonably, incensed, and wrote to Halley concerning it in somewhat acrimonious terms. Halley, who seems to have acted throughout a very creditable part, replied by urging that Hooke's conduct had been represented in worse colors than it deserved; whereupon Newton not only expressed his regret for the angry "postscript to his last," but agreed, with the view of "composing the dispute," to insert into the text of his book the following acknowledgment:

"The inverse law of gravity holds in all the celestial motions, as was discovered also independently by my countrymen, Wren, Hooke, and Halley."*

How far Hooke was pacified by this concession does not appear; but there is evidence that he continued, although in a lower key, to claim ownership in the discovery of gravity. It was, indeed, difficult for him to see with equanimity the great scientific prize of the century, which he had set before him as the crowning glory of his own career, carried off before his eyes by a swifter competitor; and he could not be expected to recognize, what to us is evident enough, that his powers were wholly unequal to the unique achievement of his rival. The intuition of a discovery is one thing, its demonstration another; and, while the one excites our interest and curiosity, it is to the other that we justly apportion our unqualified admiration.

Between Hooke and Newton no further intercourse seems at any time to have been set on foot. If Hooke was jealous of Newton, Newton was perhaps somewhat ungenerous toward Hooke. He recognized his merits with reluctance, and acknowledged his inventions only by compulsion. Broils and disquietudes, and the fomentors and originators thereof, were in truth odious to him; and he was at all times disposed to conceal a discovery, rather than risk a controversy. "Philosophy," he wrote to Halley,† "is such an impertinently litigious lady, that a man had as good be engaged in lawsuits as have to do with her." Thus the turmoil raised by Hooke on the appearance of the first part of the "Principia" inspired him with so deep a disgust that he seriously contemplated suppressing the remainder; and he could never be induced to publish his work on "Optics" until the death of his unquiet opponent had secured for it a peaceful reception. But the most significant fact as regards the relations of these two men is that Newton,

* Scholium to the Fourth Proposition in First Book of "Principia." Brewster, "Life of Newton," vol. i., p. 311.

† Letter of June 20, 1686, "Biographia Britannica," article "Halley."

who, during Hooke's lifetime had never sat at the council-table of the Royal Society, was, only a few months after his decease, elected both to that position and the still higher one of President, on the same day, November 30, 1703.

Not much now remains to be said. Hooke's growing infirmities of mind and body condemned him to isolation; and isolation is the chosen ally of eccentricity. Repeated disappointments had aggravated the inherent moroseness of his disposition; increasing ill health soured his naturally irritable temper; and the death, in 1687, of his niece, Mrs. Grace Hooke—probably the only person in the world for whom he entertained a sincere attachment—broke the last link uniting him to every-day humanity. Still he pursued his investigations with a feverish energy that age and sickness seemed rather to stimulate than to quell. His jealousy of piratical appropriation increased, with advancing years, almost to a mania; he enveloped his researches in a mysterious reserve; and many of the discoveries which he professed to have made, descended with him into the grave. Among these were a means of finding the longitude at sea, and a secret for perfecting all kinds of optical instruments. It might be conjectured, from the small size of some telescopes used by him, that this latter invention approached that of achromatism (made by Dollond in the middle of the following century); but, on the other hand, we find him laying it down as an axiom that increased power could only be obtained by increased focal length; and he is even said to have entertained as a possibility the construction of an instrument ten thousand feet long, which should bring into view the inhabitants of the moon! We can not, indeed, take his own word for his performances. He was probably not deliberately untruthful; but he was sanguine as well as vain, and apt to discourse largely of results, toward which imagination pointed, but which reason had not yet grasped. The Royal Society, at any rate, so far believed his professions as to make him, in 1696, a grant for the purpose of completing his researches and recording his discoveries. The remaining years of his life and his failing physical powers were dedicated, with almost insane zeal, to the task of raising an adequate monument to his experimental genius. Disease was powerless to divert him from his purpose; fatigue never seemed to approach him. Day after day, and night after night, he meditated, experimented, invented. For several years before his death, he was said never to have undressed or gone to bed. His limbs swelled, his brain reeled, his very eyesight failed; but still he worked, and wrote, and dreamed of immortality. At length a summons came which he was powerless to resist. He died on March 3, 1703, unloved, unlamented, and, at least in his own apprehension, unrecognized. He died, as he had lived, haunted by unfulfilled hopes, and deluded with abortive projects. In the midst of voluntary destitution, he had cherished a magnificent design for the endowment of the Royal Society. But he left no testamentary disposition of his

hoarded wealth, which proved as barren after his death as it had been during his life.

Imprisoned in his own egotism, he did not know how to contribute his quota generously to the long day's labor of humanity. He sought to set his trade-mark on every thought. He would have desired a patent of protection for every experiment. His work was in consequence visited with the curse of sterility. A slave to *meum* and *tuum*—in his own words, "the great rudder of human affairs"—his peevish reclamations were met with the inexorable *Sic vos non vobis* of ironical destiny. Of the innumerable inventions which he originated, scarcely one has been associated with his name. His suggestions bore fruit in the hands of others. His ideas were appropriated and perfected by his rivals. His experiments conferred luster on his successors. By tacit consent, his intellectual inheritance was divided, and his claims ignored. Newton took up the theory of light where he abandoned it, and left him far behind in the momentous search for the law of gravitation. Mayow carried forward the investigations which he had set on foot as to the purpose subserved by the air in respiration.* His method was used by Picard in 1670, with striking success, in his new measurement of the earth. His observations formed the basis upon which Bradley founded, in 1728, his discovery of the aberration of light. That his repeated disappointments and mischances were in any degree attributable to his own deficiencies, naturally did not occur to him. It was simpler and more consolatory to set them down to the prevalent malignity and injustice of mankind. Hence the deepening shade of misanthropy which enveloped in saturnine reserve the later years of his life.

Nevertheless, Hooke was, in spite of conspicuous defects, by no means a bad man. His morals were irreproachable, his diligence was untiring, and his religious sentiments seem to have been unfeignedly devout. His faults were warpings of the mind, closely dependent, perhaps, on his unfortunate physical constitution. In spirit, as well as in person, Nature had set him somewhat awry. "Certainly," writes Bacon, "there is a consent between the body and the mind; and where Nature erreth in the one, she ventureth in the other. *Ubi peccat in uno, periclitatur in altero.*" It was his misfortune that he could neither win sympathy nor inspire pity. His talents earned for him patronage; but his peculiarities repelled friendship. He lived sixty-eight years without attaching to himself a single human being, and died only to make room for his rival. And yet his intellectual qualities did not demand admiration more than his moral failings claimed tenderness. For surely infirmity has been rarely combined with genius in more painful and pitiable guise than in Robert Hooke.—*Edinburgh Review.*

* For an interesting account of Mayow's experiments, see Miss Buckley's "Short History of Science," p. 131.

CRITICISMS CORRECTED.

By HERBERT SPENCER.

I. TAIT AND KIRKMAN.

ONE way of estimating the validity of a critic's judgments is that of studying his mental peculiarities as generally displayed. If he betrays idiosyncrasies of thought in his writings at large, it may be inferred that these idiosyncrasies possibly, if not probably, give a character to the verdicts he passes upon the productions of others. I am led to make this remark by considering the probable connection between Professor Tait's habit of mind as otherwise shown and as shown in the opinion he has tacitly expressed respecting the formula of evolution.

Daily carrying on experimental researches, Professor Tait is profoundly impressed with the supreme value of the experimental method; and has reached the conviction that by it alone can any physical knowledge be gained. Though he calls the ultimate truths of physics "axioms," yet, not very consistently, he alleges that only by observation and experiment can these "axioms" be known as such. Passing over this inconsistency, however, we have here to note the implied proposition that, where no observation or experiment is possible, no physical truth can be established; and, indeed, that in the absence of any possibility of experiment or observation there is no basis for any physical belief at all. Now, "The Unseen Universe," a work written by him in conjunction with Professor Balfour Stewart, contains an elaborate argument concerning the relations between the universe which is visible to us and an invisible universe. This argument, carried on in pursuance of physical laws established by converse with the universe we know, extends them to the universe we do not know: the law of the conservation of energy, for example, being regarded as common to the two, and the principle of continuity, which is traced among perceptible phenomena, being assumed to hold likewise of the imperceptible. On the strength of these reasonings, conclusions are drawn which are considered as at least probable: support is found for certain theological beliefs. Now, clearly, the relation between the seen and the unseen universes can not be the subject of any observation or experiment; since, by the definition of it, one term of the relation is absent. If we have, then, no warrant for asserting a physical axiom save as a generalization of results of experiments—if, consequently, where no observation or experiment is possible, reasoning after physical methods can have no place—then there can be no basis for any conclusion respecting the physical relations of the seen and the unseen universes. Not so, however, concludes Professor Tait. He thinks that, while no validity can be claimed for our judgments respecting

perceived forces, save as experimentally justified, some validity can be claimed for our judgments respecting unperceived forces, where no experimental justification is possible.

The peculiarity thus exhibited in Professor Tait's general thinking is exhibited also in some of his thinking on those special topics with which he is directly concerned as a Professor of Physics. An instance was given by Professor Clerk-Maxwell when reviewing, in "Nature," for July 3, 1879, the new edition (1879) of Thomson and Tait's "Treatise on Natural Philosophy." Professor Clerk-Maxwell writes: "Again, at page 222, the capacity of the student is called upon to accept the following statement: 'Matter has an innate power of resisting external influences, so that every body, as far as it can, remains at rest or moves uniformly in a straight line.' Is it a fact that 'matter' has any power, either innate or acquired, of resisting external influences?" And, to Professor Clerk-Maxwell's question thus put, the answer of one not having a like mental peculiarity with Professor Tait must surely be—No.

But the most remarkable example of Professor Tait's mode of thought, as exhibited in his own department, is contained in a lecture which he gave at Glasgow when the British Association last met there (see "Nature," September 21, 1876)—a lecture given for the purpose of dispelling certain erroneous conceptions of force commonly entertained. Asking how the word force "is to be correctly used," he says: "Here we can not but consult Newton. The sense in which he uses the word 'force,' and therefore the sense in which we must continue to use it if we desire to avoid intellectual confusion, will appear clearly from a brief consideration of his simple statement of the laws of motion. The first of these laws is: *Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it is compelled by impressed forces to change that state.*" Thus Professor Tait quotes, and fully approves, that conception of force which regards it as something which changes the state of a body. Later on in the course of his lecture, after variously setting forth his views of how force is rightly to be conceived, he says, "Force is the rate at which an agent does work per unit of length." Now let us compare these two definitions of force. It is first, on the authority of Newton emphatically endorsed, said to be that which changes the state of a body. Then it is said to be the rate at which an agent does work (doing work being equivalent to changing a body's state). In the one case, therefore, force itself is the agent which does the work or changes the state; in the other case, force is the rate at which some other agent does the work or changes the state. How are these statements to be reconciled? Otherwise put, the difficulty stands thus: force is that which changes the state of a body; force is a rate, and a rate is a relation (as between time and distance, interest and capital); therefore a relation changes the state of a body. A relation is no longer a *nexus* among phenomena, but becomes a producer of phenomena. Whether Professor Tait succeeded

in dispelling "the widespread ignorance as to some of the most important elementary principles of physics," whether his audience went away with clear ideas of the "much-abused and misunderstood term" force, the report does not tell us.

Let us pass now from these illustration of Professor Tait's judgment, as exhibited in his special department, to the consideration of his judgment on a wider question here before us—the formula of evolution. In "Nature," for July 17, 1879, while reviewing Sir Edmund Beckett's "Origin of the Laws of Nature," and praising it, he says of the author: "He follows, in fact, in his own way, the hint given by a great mathematician (Kirkman), who made the following exquisite translation of a well-known definition: 'Evolution is a change from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity, through continuous differentiations and integrations.'* [*Translation into plain English:*] Evolution is a change from a nohowish, untalkaboutable all-alikeness to a somehowish and in-general-talkaboutable not-all alikeness, by continuous somethingelseifications and sticktogetherations."

Professor Tait, proceeding then to quote from Sir Edmund Beckett's book passages in which, as he thinks, there is a kindred tearing off of disguises from the expressions used by other authors, winds up by saying—"When the purposely vague statements of the materialists and agnostics are thus stripped of the tinsel of high-flown and unintelligible language, the eyes of the thoughtless who have accepted them on authority (!) are at last opened, and they are ready to exclaim with Titania, methinks, 'I was enamored of an ass.'" And that Mr. Kirkman similarly believes that his travesty proves the formula of evolution to be meaningless, is shown by the sentence which follows it: "Can any man show that my translation is unfair?"

One would have thought that Mr. Kirkman and Professor Tait, however narrowly they limited themselves to their special lines of inquiry, could hardly have avoided observing that in proportion as scientific terms express wider generalities, they necessarily lose that vividness of suggestion which words of concrete meanings have; and, therefore, to the uninitiated seem vague, or even empty. If Professor Tait enunciated to a rustic the physical axiom, "action and reaction are equal and opposite," the rustic might, not improbably, fail to form any corresponding idea. And he might, if his self-confidence were akin to that of Mr. Kirkman, conclude that where he saw no meaning

* A conscientious critic usually consults the latest edition of the work he criticises, so that the author may have the benefit of any corrections or alterations he has made. Apparently, Mr. Kirkman does not think such a precaution needful. Publishing, in 1876, his "Philosophy without Assumptions," from which the above passage is taken, he quotes from the first edition of "First Principles," published in 1862; though in the edition of 1867, and all subsequent ones, the definition is, in expression, considerably modified—two of the leading words being no longer used.

there could be no meaning. Further, if, after the axiom had been brought partially within his comprehension by an example, he were to laugh at the learned words used and propose to say instead, "shoving and back-shoving are one as strong as the other," it would possibly be held by Professor Tait that this way of putting it is hardly satisfactory. If he thought it worth while to enlighten the rustic, he might, perhaps, point out to him that his statement did not include all the facts—that not only shoving and back-shoving, but also pulling and back-pulling, are one as strong as the other. Supposing the rustic were not too conceited, he might eventually be taught that the abstract, and to him seemingly vague, formula, "action and reaction are equal and opposite," was chosen because by no words of a more specific kind could be expressed the truth in its entirety. Professor Tait, however, and Mr. Kirkman, though the physical and mathematical terms they daily employ are so highly abstract as to prove meaningless to those who are unfamiliar with the concrete facts covered by them, seem not to have drawn any general inference from this habitual experience. For, had they done so, they must have been aware that a formula expressing all orders of changes in their general course—astronomic, geologic, biologic, psychologic, sociologic—could not possibly be framed in any other than words of the highest abstractness. Perhaps there may come the rejoinder that they do not believe any such universal formula is possible. Perhaps they will say that the on-going of things, as shown in our planetary system, has nothing in common with the on-going of things which has brought the earth's crust to its present state, and that this has nothing in common with the on-going of things which the growths and actions of living bodies show us; although, considering that the laws of molar motion and the laws of molecular action are proved to hold true of them all, it requires considerable courage to assert that the modes of coöperation of the physical forces in these several regions of phenomena present no traits in common. But, unless they allege that there is one law for the redistribution of matter and motion in the heavens, and another law for the redistribution of matter and motion in the earth's inorganic masses, and another law for its organic masses—unless they assert that the transformation everywhere in progress follows here one method and there another—they must admit that the proposition which expresses the general course of the transformation can do it only in terms remote in the extremest degree from words suggesting definite objects and actions.

After noting the unconsciousness thus betrayed by Mr. Kirkman and Professor Tait, that the expression of highly abstract truths necessitates highly abstract words, we may go on to note a scarcely less remarkable anomaly of thought shown by them. Mr. Kirkman appears to think, and Professor Tait apparently agrees with him in thinking, that when one of these abstract words, coined from Greek or Latin roots, is transformed into an uncouth-looking combination of

equivalents of Saxon, or rather old English origin, what they regard as its misleading glamour is thereby dissipated and its meaninglessness made manifest. We may conveniently observe the nature of Mr. Kirkman's belief by listening to an imaginary addition to that address before the Literary and Philosophical Society of Liverpool in which he first set forth the leading ideas of his volume; and we may fitly, in this imaginary addition, adopt the manner in which he delights:

"Observe, gentlemen," we may suppose him saying, "I have here the yolk of an egg. The evolutionists—using their jargon—say that one of its characters is 'homogeneity'; and, if you do not examine your thoughts, perhaps you may think that the word conveys some idea. But, now if I translate it into plain English, and say that one of the characters of this yolk is 'all-alikeness,' you at once perceive how nonsensical is their statement. You see that the substance of the yolk is not all-alike, and that therefore all-alikeness can not be one of its attributes. Similarly with the other pretentious term, 'heterogeneity,' which, according to them, describes the state things are brought to by what they call evolution. It is mere empty sound, as is manifest if I do but transform it, as I did the other, and say instead 'not-all-alikeness.' For, on showing you this chick, into which the yolk of the egg turns, you will see that 'not-all-alikeness' is a character which can not be claimed for it. How can any one say that the parts of the chick are not-all-alike? Again, in their blatant language we are told that evolution is carried on by continuous 'differentiations'; and they would have us believe that this word expresses some fact. But, if we put instead of it 'somethingelseifications,' the delusion they try to practice on us becomes clear. How can they say that while the parts have been forming themselves the heart has been becoming something else than the stomach, and the leg something else than the wing, and the head something else than the tail? The like manifestly happens when for 'integrations' we read 'sticktogetherations': what sense the term might seem to have becomes obvious nonsense when the substituted word is used. For nobody dares assert that the parts of the chick stick together any more than do the parts of the yolk. I need hardly show you that now when I take a portion of the yolk between my fingers and pull, and now when I take any part of the chick, as the leg, and pull, the first resists just as much as the last, the last does not stick together any more than the first; so that there has been no progress in 'sticktogetherations.' And thus, gentlemen, you perceive that these big words which, to the disgrace of the Royal Society, appear even in papers published by it, are mere empty bladders, which these would-be philosophers use to buoy up their ridiculous doctrines."

There is a further curious mental trait exhibited by Mr. Kirkman, and which Professor Tait appears to have in common with him. Very truly it has been remarked that there is a great difference between disclosing the absurdities contained *in* a thing and piling absurdities *upon*

it; and a remark to be added is that some minds appear incapable of distinguishing between intrinsic absurdity and extrinsic absurdity. The case before us illustrates this remark; and at the same time shows us how analytical faculties of one kind may be constantly exercised without strengthening analytical faculties of another kind—how mathematical analysis may be daily practiced without any skill in psychological analysis being acquired. For, if these gentlemen had analyzed their own thoughts to any purpose, they would have known that incongruous juxtapositions may, by association of ideas, suggest characters that do not at all belong to the things juxtaposed. Did Mr. Kirkman ever observe the result of putting a bonnet on a nude statue? If he ever did, and if he then reasoned after the manner exemplified above, he doubtless concluded that the obscene effect belonged intrinsically to the statue, and only required the addition of the bonnet to make it conspicuous. The alternative conclusion, however, which perhaps most will draw, is that not in the statue itself was there anything of an obscene suggestion, but that this effect was purely adventitious: the bonnet, connected in daily experience with living women, calling up the thought of a living woman with the head dressed but otherwise naked. Similarly though, by clothing an idea in words which excite a feeling of the ludicrous by their oddity, any one may associate this feeling of the ludicrous with the idea itself, yet he does not thereby make the idea ludicrous; and, if he thinks he does, he shows that he has not practiced introspection to much purpose.

By way of a lesson in mental discipline, it may be not uninstructive here to note a curious kinship of opinion between these two mathematicians and two *littérateurs*. At first sight it appears strange that men, whose lives are passed in studies so absolutely scientific as those which Professor Tait and Mr. Kirkman pursue, should, in their judgments on the formula of evolution, be at one with two men of exclusively literary culture—a North American Reviewer and Mr. Matthew Arnold. In the "North American Review," vol. cxx., page 202, a critic, after quoting the formula of evolution, says, "This may be all true, but it seems at best rather the blank form for a universe than anything corresponding to the actual world about us." On which the comment may be, that one, who had studied celestial mechanics as much as the critic has studied the general course of transformations, might similarly have remarked that the formula, "bodies attract one another directly as their masses and inversely as the squares of their distances," was at best but a blank form for solar systems and sidereal clusters. With this parenthetical comment, I pass to the fact above hinted, that Mr. Matthew Arnold obviously coincides with the critic's estimate of the formula. In Chapter V. of his work "God and the Bible," when preparing the way for a criticism on German theologians as losing themselves in words, he quotes a saying from Homer. This he introduces by remarking that "it is not at all a grand one. We are almost

ashamed to quote it to readers who may have come fresh from the last number of the 'North American Review,' and from the great sentence there quoted as summing up Mr. Herbert Spencer's theory of evolution, 'Evolution is, etc.' Homer's poor little saying comes not in such formidable shape. It is only this: *Wide is the range of words! words may make this way or that way.*" And then he proceeds with his reflections upon German logomachies. All of which makes it manifest that, going out of his way, as he does, to quote this formula from the "North American Review," he intends tacitly to indicate his agreement in the reviewer's estimate of it.

That these two men of letters, like the two mathematicians, are unable to frame ideas answering to the words in which evolution at large is expressed, seems manifest. In all four, the verbal symbols used call up either no images, or images of the vaguest kinds, which, grouped together, form but the most shadowy thoughts. If, now, we ask what is the common trait in the education and pursuits of all four, we see it to be lack of familiarity with those complex processes of change which the concrete sciences bring before us. The men of letters, in their early days dieted on grammars and lexicons, and in their later days occupied with *belles-lettres*, biography, and a history made up mainly of personalities, are by their education and course of life left almost without scientific ideas of a definite kind. The universality of physical causation, the interpretation of all things in terms of a never-ceasing redistribution of matter and motion, is naturally to them an idea utterly alien. The mathematician, too, and the mathematical physicist, occupied exclusively with the phenomena of number, space, and time, or, in dealing with forces, dealing with them in the abstract, carry on their researches in such ways as may, and often do, leave them quite unconscious of the traits exhibited by the general transformations which things, individually and in their totality, undergo. In a chapter on "Discipline," in the "Study of Sociology," I have commented upon the uses of the several groups of sciences—abstract, abstract-concrete, and concrete—in cultivating different powers of mind; and have argued that while, for complete preparation, the discipline of each group of sciences is indispensable, the discipline of any one group alone, or any two groups, leaves certain defects of judgment. Especially have I contrasted the analytical habit of thought which study of the abstract and abstract-concrete sciences produces with the synthetical habit of thought produced by study of the concrete sciences. And I have exemplified the defects of judgment to which the analytical habit, unqualified by the synthetical habit, leads. Here we meet with a striking illustration. Scientific culture of the analytical kind, almost as much as absence of scientific culture, leaves the mind bare of those ideas with which the concrete sciences deal. Exclusive familiarity with the *forms* and *factors* of phenomena no more fits men for dealing with the *products* in their totalities than does mere literary study.

THE INDIA-RUBBER INDUSTRIES.*

By THOMAS BOLAS, F. C. S.

INDIA-RUBBER, or caoutchouc, possesses properties so widely different from those of most other substances that it became an object of very great interest as soon as it made its appearance in the civilized world, and its industrial importance has rapidly increased as the knowledge of its remarkable characters and manifold applicability has become more extended. At the present time, caoutchouc holds such an important position with regard to the economy of modern arts and manufactures, that, were it suddenly to be withdrawn from circulation, many minor industries would in consequence cease to exist; while numerous large and important branches of handicraft would languish until arrangements could be made to adapt their operations to the altered circumstances.

It is, however, during the last forty years that India-rubber has enjoyed its greatest triumphs as an industrial agent—that is to say, since the art of vulcanization was discovered and perfected by the labors of Charles Goodyear, Thomas Hancock, and others.

The earliest rumor of the existence of caoutchouc reached Europe nearly five hundred years ago; the first visit of Columbus to Hayti having brought to light the fact that the natives of this island were in the habit of making playing-balls of an elastic gum. Nothing more appears to have been heard of India-rubber until Torquemada, rather over two hundred and fifty years ago, described the Mexican Indians as not only making playing-balls of India-rubber, but also as fabricating helmets, shoes, water-proof fabrics, and other articles of elastic gum. This writer gives some details as to the collection of the juice and the making of various articles from it, thus giving us the first view of the India-rubber manufacture as a branch of industry. We do not hear, however, of samples of India-rubber reaching Europe until long after this, and little more appears to have been learned regarding the substance until the celebrated French naturalist, La Condamine, made a communication to the Academy of Sciences at Paris concerning caoutchouc, he having had ample opportunities of studying the subject in Para. In the memoir in question, La Condamine gives very detailed particulars regarding the Para India-rubber tree, the collection and treatment of the juice, and the methods made use of by the natives for the production of various articles of caoutchouc. He tells us that the substance in question was used for making torches, these being only an inch and a half in diameter by two feet long, and yet burning for twelve hours. Again we hear of the use of India-rubber for the making of playing-balls, and it appears that the natives were in the habit of using enema or injection bottles made of caoutchouc.

* Lecture before the London Society of Arts.

Soon after La Condamine's communication to the Academy of Sciences, samples of India-rubber frequently reached Europe, and scientific men began to make investigations regarding this remarkable body. Between 1760 and 1770 we find Fresneau and Macquer studying the subject, and the last-named investigator made tubes and other articles of caoutchouc by dissolving it in ether and coating molds with the solution, so that a solid skin of caoutchouc should remain adherent to the mold on the evaporation of the solvent.

From this time until the end of the eighteenth century, the India-rubber industry may be considered to have been undergoing its period of gestation, and to have been born with the dawn of the present century. Among the first of the important patents regarding the utilization of caoutchouc is that granted in 1823 to Charles Macintosh, for dissolving the substance in coal-oil, or coal-naphtha, and the use of this solution as a water-proofing agent. I have here a specimen of such a solution, as now manufactured by Messrs. Charles Macintosh and Co., of Manchester, together with some examples illustrating its uses.

About the same time, elastic webbing was first made with threads cut from the raw rubber, and other minor applications of caoutchouc to the industrial arts were adopted from time to time, until the great discovery of vulcanization inaugurated a new epoch in this branch of industry, rendering it possible to so far alter caoutchouc as to make it capable of resisting, to a great extent, the action of heat on the one hand and cold on the other hand.

The milky sap of many plants contains caoutchouc, suspended in the form of minute transparent globules, these being frequently as small as $\frac{1}{20000}$ to $\frac{1}{80000}$ of an inch in diameter; but comparatively few plants contain sufficient caoutchouc to render them important sources of this body.

The trees which yield the largest supply of the best quality of caoutchouc consist of various species of hevea, which flourish in the northern districts of South America, especially in the province of Para, some portions of the valley of the Amazon being crowded to an extraordinary extent with heveas. The abundance of the India-rubber trees in Para may be judged of by the fact that this province alone exported 7,340 tons of caoutchouc in the year 1877, more than half of this being sent to Liverpool.

Among the heveas most productive of caoutchouc may be mentioned the *Hevea Brasiliensis*, which flourishes in Para, and yields some of the finest caoutchouc, and often attains a height of sixty to seventy feet, with a diameter of nearly three feet; the *Hevea Guianensis*, a similarly magnificent tree, likewise abundantly productive of caoutchouc; and the *Hevea spruceana*, a smaller tree, which grows almost exclusively in the province of Para. Fig. 1 represents the flowers and foliage of *Hevea Guianensis*.

In the operation of collecting the juice several cuts are made through the bark of the tree, and either shells or clay vessels are attached to receive the exuding milky sap. When sufficient of this has been collected, the operation of drying it is performed as follows: A kind of

FIG. 1.—HEVEA GUIANENSIS (FLOWER AND FOLIAGE).

wooden bat, thinly covered over with clay, is dipped into a pail filled with the juice, and the bat, thus coated, is held over a fire, fed with certain wild nuts, which, in burning, give off abundance of aromatic smoke. Fig. 2 represents this operation, and you will see that a kind

of short chimney is fixed over the fire to lead the smoke compactly upward. As soon as the first layer of juice has become indurated, the bat is again dipped, and the drying operation is repeated, layer after layer being thus dried on the bat, until a thickness of nearly an inch is attained. A knife-cut is now made in the bottle or biscuit of caoutchouc thus obtained, so that it can be removed from the wooden bat, and exposed to the air to become still further indurated. Para caoutchouc, prepared in this manner, has a fragrant, aromatic odor, which you can study for yourselves in the samples now before you.

The residues of juice left in the various vessels employed, the scrapings of the incisions, together with other materials, which the ingenious native thinks he can shuffle off on the unsuspecting merchant as caoutchouc, are made into balls, and sold as "negro-head." The negro-head rubber is frequently made into crude representations of animals, and there are several such works of native art on the table—as, for example, this specimen, which will pass about equally well for a horse, a pig, or a crocodile.

Here is a piece of Para bottle-rubber, which has been boiled for some hours in water, and you see that it is now so far softened as to render it easy to pull asunder the several layers of which it is composed, its laminated structure being thus very well illustrated.

The milky juice of the Para rubber trees, of which you see a specimen before you, has approximately the following composition :

Caoutchouc	32
Albuminous, extractive, and saline matters	12
Water	56
Total	100

As a rubber-producing tree, the *Ficus elastica* stands next in importance of the heveas. The *Ficus elastica* grows abundantly in India and the East Indian Islands, one district in Assam, thirty miles long by eight miles wide, being said to contain 43,000 trees, many of them attaining a height of a hundred feet. This tree also grows freely in Madagascar, and it is well known to us as a greenhouse plant. Fig. 3 represents a *Ficus elastica* now growing out of doors in the Parc Monceau at Paris.

The juice of the *Ficus elastica* contains notably less caoutchouc than that of the American trees, the proportion very often falling as low as ten per cent. of the juice.

A vine-like plant, the *Urceola elastica*, which grows abundantly in Madagascar, Borneo, Singapore, Sumatra, Penang, and other places, yields a considerable amount of caoutchouc of very good quality. Africa yields a considerable quantity of caoutchouc, but generally soft and of inferior quality. It is believed to be yielded by various species of landolphia, ficus, and toxicophlea. Here are some specimens of African rubber—this specimen, representing the quality known as

African ball, being tolerably firm in consistency, while the African flake, which you see here, and the African tongue, represent the lowest and most viscous qualities of commercial rubber.

The commercial value of the various qualities of rubber may be estimated, to a certain extent, by noting the loss which the samples undergo during the operation of washing, and also by noticing how far the various samples are softened by a long-continued gentle heat. Here are some samples which have been heated for some hours in this water-oven; you will notice that the African tongue has become almost as soft as treacle, while the Para rubber still retains its form and much of its consistency.

Caoutchouc is nearly colorless, and when in thin leaves tolerably transparent. It, like very many other substances, contains nothing but carbon and hydrogen, but its properties differ very widely from those of other hydrocarbons almost identical in composition. It has been found to contain, in one hundred parts, 12·5 of hydrogen and 87·5 of carbon. Caoutchouc, as might be supposed, burns very readily and leaves no residue; if I set fire to a few ounces, you see how it blazes up. It is soft, and very imperfectly elastic, in the true sense of the term—that is to say, it does not return to its old dimensions after having been considerably stretched. Here is a strip of pure (i. e., unvulcanized) caoutchouc a foot long; you see that I have stretched it to a length of three feet, and, after holding it stretched for a few seconds, I relax it. It now measures, as you see, several inches over the foot. The elasticity of caoutchouc may be enormously increased by vulcanization.

As regards the stretching of India-rubber, there is a point at which it requires a greatly increased force to stretch it, and at this point it seems to become fibrous in texture, as you may perceive by examiniug this extended sample by the aid of a magnifying-lens. India-rubber has valuable electrical properties, as you are no doubt aware, it being an admirable insulator, and having a great tendency to become electrical by friction.

Freshly cut surfaces of India-rubber cohere very strongly when brought into contact, and this is well illustrated by the old way of making a tube of unvulcanized caoutchouc. You see that I wrap a sheet of caoutchouc round a mandrel, so that the edges project parallel to each other. These parallel edges being cut off by means of scissors, the freshly cut edges adhere, and a perfect tube is the result. Toy balloons are made in a somewhat analogous manner, and are cold vulcanized afterward.

Either French chalk or soapy water is of constant use in the rubber-factories, to prevent the adhesion of new surfaces of caoutchouc to each other, or to other substances.

Cold has a remarkable effect on caoutchouc, rendering it rigid and inelastic, and this circumstance considerably detracts from the value

of unvulcanized India-rubber. Here is a strip of India-rubber; you see that it is quite soft and pliable. I will now expose it for a few minutes to a temperature of 0° Centigrade, or the freezing-point of

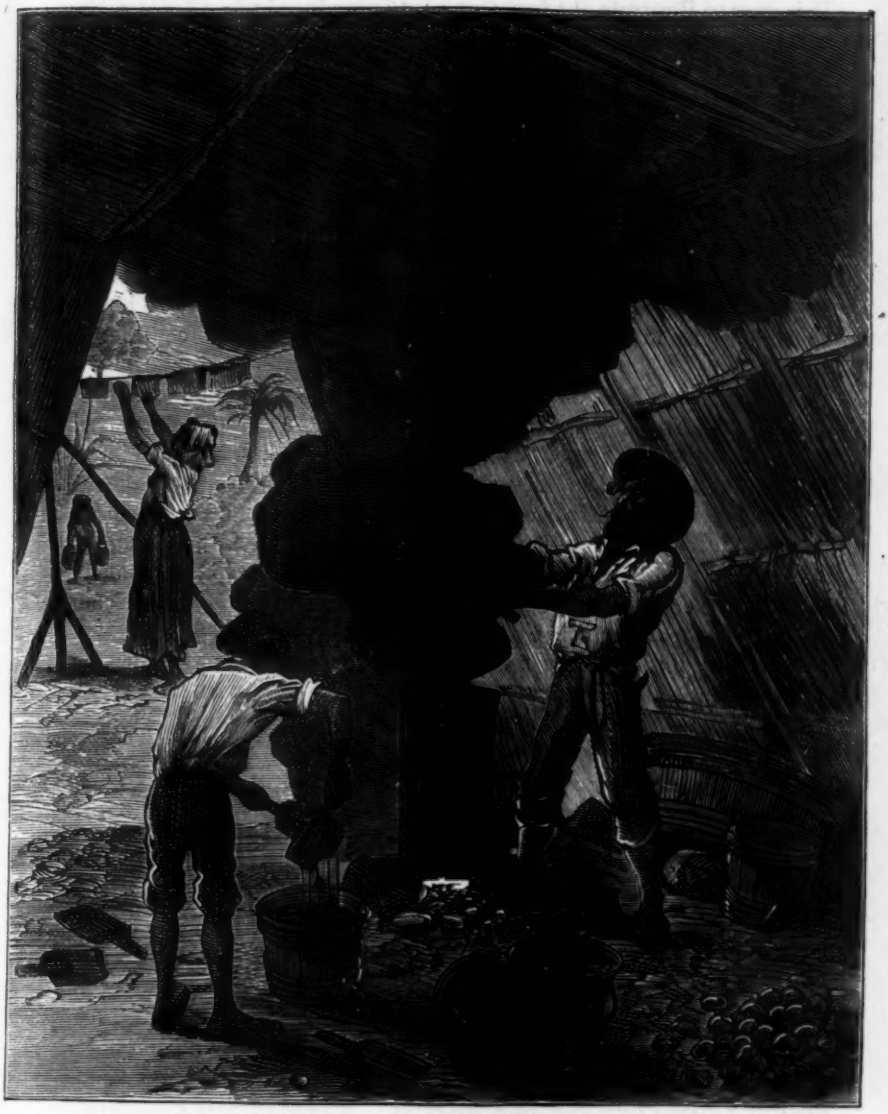


FIG. 2.—THE OPERATION OF DRYING THE INDIA-RUBBER JUICE.

water. It becomes, as you see, rigid and stiff, but its original pliability may be restored, either by warming, or by applying sufficient tensile strain to it, to extend it to three or four times its length. One half

of this strip I will warm in water, heated to 50° Cent., and the other I will stretch. In each case you see that the caoutchouc is restored to its original condition. In the case of the stretching it is very likely that the effect is due to the heat evolved during that operation. It is easy to illustrate the fact that heat is produced when India-rubber is subjected to tension. Here are some strips of India-rubber, arranged side by side on a board. I bring them in contact with the bulb of an air-thermometer, and you see that there is no indication of either heat or cold. The strips of India-rubber being now stretched to four or five times their previous length, the air-thermometer indicates a considerable rise of temperature. Here is a similar set of strips, which were stretched some hours ago, and which on trial by the air-thermometer we now find to have cooled down to the temperature of the surrounding objects. Note the effect of releasing the tension and allowing the rubber strips to contract. You see that they have become so cold as to influence the air-thermometer to a very considerable extent.

The effects of heat on India-rubber present many points of interest, and, in the first place, I wish to illustrate to you the effect of moderate heat on a stretched band of caoutchouc. Here is such a band, one end being attached to an index, pointing, at the present time, to the zero of this paper scale. Notice the consequence of applying a gentle heat to the caoutchouc band—it contracts as regards its length, but expands in a transverse direction, causing the index to move rapidly through a space of several degrees. This property, which stretched caoutchouc possesses, of contracting by heat, may be described by saying that, within certain limits, the tensile elasticity of caoutchouc is increased by an elevation of temperature. Caoutchouc, however, if heated to 100° Cent., softens considerably, and almost entirely loses its elasticity, as you will perceive by examining this sample, which has been heated for some hours; while a heat of 120° Cent. produces a most decided softening effect on caoutchouc of the best quality, but after exposure to this temperature, it recovers its pristine state by exposure to cold for a moderate period. If, however, the action of heat has been pushed still further, say to 200 Cent., the caoutchouc becomes converted into a permanently viscous body, which has little or no tendency to harden again. This viscous substance possesses the same composition as unaltered caoutchouc, and is of value as a medium for making air-tight joints, which can be easily undone. This glass jar has its top edge ground level, and, after applying a little of the heated caoutchouc to the ground edge, the jar may, as you see, be hermetically closed by a disk of plate-glass. A joint of this kind may be broken and remade with the utmost facility and rapidity.

When caoutchouc is subjected to a temperature somewhat above 200 Cent., it becomes converted into a variety of volatile hydrocarbons, which present many points of interest, and you will find a toler-

ably full account of them in the manuals of chemistry. In this retort, the dry distillation of caoutchouc is being carried on, and in time very nearly the whole of the India-rubber will be converted into the mixture of oily hydrocarbons, only an insignificant carbonaceous residue remaining in the retort. The mixture of volatile hydrocarbons, often referred to as caoutchoucine, forms a very good solvent for caoutchouc and certain resinous bodies.

India-rubber is subject to two kinds of deterioration and decay. In one instance it tends to become soft, and loses its elasticity, while in the other it becomes friable, yellowish, and resinous in its nature. Examples of each kind of deteriorated rubber are on the table, and you will notice that, in the case of this specimen, we have a well-marked instance of both kinds of deterioration going on side by side. The last-mentioned kind of deterioration has been clearly and indubitably traced to an oxidation of the caoutchouc. This oxidation is tolerably rapid when the caoutchouc exists in a finely divided state, and when it is exposed to damp at the same time; but the alternate damping and drying of the caoutchouc tends more toward its rapid oxidation than does a continual state of dampness. The resinous matter resulting from the oxidation of caoutchouc has been carefully studied by Spiller, who found that a sample of felt, originally composed of cotton fibers and India-rubber, had become so far changed during six years as to contain no trace of caoutchouc; but in its place he found a resinous substance resembling shellac. This resinous body, of which a sample is before you is easily soluble in alcohol, and also dissolves in benzole. Alkalies dissolve it readily, and acids precipitate it from the alkaline solution. It contains 27·3 per cent. of oxygen.

The conditions under which the softening of the India-rubber takes place are not so well understood, but there is some reason to believe that this is due to incipient oxidation.

Ozone oxidizes caoutchouc with extreme rapidity, as Warren pointed out in 1877, and I have arranged a simple experiment to illustrate this fact. Through the open end of this glass passes a slow stream of air which has been slightly ozonized; that is to say, a portion of its oxygen has been converted into ozone. When the stream of ozonized air is allowed to impinge on a surface of India-rubber, you see that the surface is instantly corroded and roughened. Again, note the effect of allowing the ozonized air to act on the surface of a distended caoutchouc balloon—you see that it bursts immediately. I should mention, by the by, that in the case of these balloons the caoutchouc is slightly vulcanized, but the action of ozone on vulcanized India-rubber is similar to its action on the unvulcanized material.

It is extremely probable that the rapid deterioration of caoutchouc, which is known to take place under conditions which are not perfectly understood, is frequently due to the corrosive and oxidizing action of ozone.

Ozone, or some agent nearly resembling it, is often produced when oil of turpentine is exposed to the air, and this circumstance may per-

FIG. 3.—FICUS ELASTICA; A SPECIMEN GROWING IN THE OPEN AIR AT PARIS.

haps explain the destructive influence which oil of turpentine occasionally exercises on India-rubber.

Exposure to sunlight often causes the destruction of India-rubber, either converting it into a soft and sticky substance, or into a hard

body, less soluble in benzole than unaltered caoutchouc; and it is quite possible to obtain a photographic print by exposing a film of India-rubber under a negative, and then dissolving away, by means of benzole, those parts on which the light has not acted. Here is such a photograph made by Mr. Woodbury. I now project it on the screen, so that you may all see it. It is generally a discreet thing to keep India-rubber where it will not be exposed to the prolonged action of a powerful light, although there are cases in which exposure to light is a useful aid to the process of vulcanization. India-rubber is, to a certain extent, porous and cellular in its texture, as may be seen by a microscopical examination of a thin section. Again, if a thin leaf of caoutchouc is boiled for a long time in water, it absorbs a considerable proportion of this liquid. You see that this piece of caoutchouc has become quite milky and translucent from the absorption of water, and it probably holds, at the present time, as much as ten or fifteen per cent. of water. The amount absorbed may, in some cases, rise as high as twenty-five per cent. In a similar manner alcohol is absorbed by India-rubber, more readily than is the case with water.

Now, we pass on to a more important matter, namely, the action of such liquids as benzole or coal-naphtha on caoutchouc. Here are two cubes of Para rubber, each being three eighths of an inch across the face. One of these I will preserve as a pattern, and the other I will suspend in a bottle containing benzole. The cube suspended in the benzole will immediately begin to swell, and will continue to do so until it has attained a bulk about one hundred times as large as its original size. During the time that the cube is swelling in the benzole, a certain proportion of the caoutchouc will become dissolved out and incorporate itself with the bulk of the solvent. Now, as a matter of fact, every kind of natural India-rubber contains two distinct modifications of caoutchouc, one of which tends to swell up in such a liquid as benzole, while the other dissolves and forms a true solution. The first mentioned of these bodies may be referred to as the fibrous constituent of caoutchouc, while the second may be spoken of as the viscous constituent. The proportions in which these two bodies occur in raw rubber vary extremely, Para rubber, of good quality, containing only a small proportion of the viscous constituent, while African tongue, on the other hand, consists principally of the viscous modification of caoutchouc. The viscous constituent of caoutchouc is the agent principally concerned in the joining together of freshly cut edges of India-rubber; and, as we proceed with the study of caoutchouc, we shall see that, under certain conditions, the fibrous caoutchouc can be more or less perfectly changed into the viscous form. The treatment of the juice of the India-rubber trees is often of such a nature as to greatly deteriorate the caoutchouc obtained; a considerable proportion being thus changed from the fibrous to the viscous condition. This kind of injury to the caoutchouc can be obviated by coagulating the milky

juice, and carefully drying the clot after it has been subjected to pressure. For experimental purposes, alcohol may be employed as a coagulating agent; while, on an industrial scale, alum has been tried with apparently an excellent result. The milk is strained to remove solid impurities, after which a small proportion of alum solution is added. The clot which separates is next drained or pressed, after which it is dried. Caoutchouc dissolves more or less perfectly, according to its condition in various liquids, among which may be mentioned

FIG. 4.—CUBE OF PARA CAOUTCHOUC UNSWELLED.

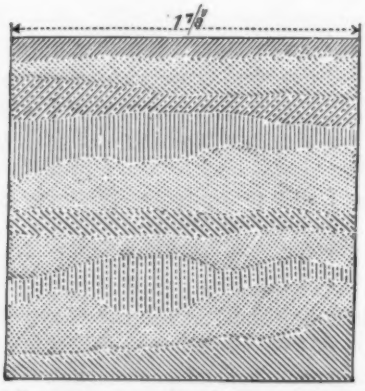


FIG. 5.—SIMILAR CUBE SWELLED BY THE PROLONGED ACTION OF BENZOLE.

the various fixed and hydrocarbon oils, chloroform, ether, and carbon disulphide. Unless, however, the caoutchouc has been masticated or otherwise degenerated, it is doubtful whether a true solution is obtained. When a clear limpid solution is required, one of the best solvents is that proposed by Payen, namely, carbon disulphide, mixed with five per cent. of absolute alcohol. If one part of masticated caoutchouc is dissolved in thirty parts of the above solvent, a solution is obtained which can be filtered through paper, and may be employed in covering the most delicate molds with successive layers of caoutchouc.

Caoutchouc may be utterly ruined by the use of impure solvents, and those experimenting with India-rubber solutions should, in cases where it is desirable to regenerate the caoutchouc by allowing the solvent to evaporate, take the utmost care not to employ any solvents which contain fatty or greasy matter.

Weak or diluted acids have little or no action on caoutchouc in the

majority of cases, but strong sulphuric acid slowly acts on it, the action becoming rapid if heat be applied. Strong nitric acid acts on it with some energy, causing its entire destruction, and in a similar manner it is destroyed by the prolonged action of chlorine, bromine, or iodine; although these reagents, when their action is kept under control, produce a vulcanizing or strengthening effect.—*Abridged from Journal of the Society of Arts.*

ON THE PRODUCTION OF SOUND BY LIGHT.*

By ALEXANDER GRAHAM BELL.

IN bringing before you some discoveries made by Mr. Sumner Tainter and myself, which, having resulted in the construction of apparatus for the production and reproduction of sound by means of light, it is necessary to explain the state of knowledge which formed the starting-point of our experiments. I shall first describe the remarkable substance selenium, and the manipulations devised by various experimenters; but the final result of our researches has extended the class of substances sensitive to light-vibrations, until we can propound the fact of such sensitiveness being a general property of all matter. We have found this property in gold, silver, platinum, iron, steel, brass, copper, zinc, lead, antimony, German silver, Jenkin's metal, Babbitt's metal, ivory, celluloid, gutta-percha, hard rubber, soft vulcanized rubber, paper, parchment, wood, mica, and silvered glass; and the only substances from which we have not obtained results are carbon and thin microscopic glass. We find that when a vibratory beam of light falls upon these substances they emit sounds, the pitch of which depends upon the frequency of the vibratory change in the light. We find, further, that, when we control the form or character of the light-vibration on selenium, and probably on the other substances, we control the quality of the sound and obtain all varieties of articulate speech. We can thus, without a conducting wire, as in electric telephony, speak from station to station, wherever we can project a beam of light. We have not had opportunity of testing the limit to which this photophonic influence can be extended, but we have spoken to and from points two hundred and thirteen metres apart; and there seems no reason to doubt that the results will be obtained at whatever distance a beam of light can be flashed from one observatory to another. The necessary privacy of our experiments hitherto has alone prevented any attempts at determining the extreme distance at which this new method of vocal communication will be available. I shall now speak of selenium.

* Lecture delivered before the American Association for the Advancement of Science, in the Institute of Technology, Boston, August 27, 1880.

In the year 1817 Berzelius and Gottlieb Gahn made an examination of the method of preparing sulphuric acid in use at Gripsholm. During the course of this examination, they observed in the acid a sediment of a partly reddish, partly clear brown color, which, under the action of the blowpipe, gave out a peculiar odor, like that attributed by Klaproth to tellurium. As tellurium was a substance of extreme rarity, Berzelius attempted its production from this deposit; but he was unable, after many experiments, to obtain further indications of its presence. He found plentiful signs of sulphur mixed with mercury, copper, zinc, iron, arsenic, and lead, but no trace of tellurium. It was not in the nature of Berzelius to be disheartened by this result. In science every failure advances the boundary of knowledge as well as every success, and Berzelius felt that, if the characteristic odor that had been observed did not proceed from tellurium, it might possibly indicate the presence of some substance then unknown to the chemist. Urged on by this hope he returned with renewed ardor to his work. He collected a great quantity of the material, and submitted the whole mass to various chemical processes. He succeeded in separating successively the sulphur, the mercury, the copper, the tin, and the other known substances whose presence had been indicated by his tests—and, after all these had been eliminated, there still remained a residue which proved upon examination to be what he had been in search of—a new elementary substance. The chemical properties of this new element were found to resemble those of tellurium in so remarkable a degree that Berzelius gave to the substance the name of "selenium," from the Greek word *selene*, the moon ("tellurium," as is well known, being derived from *tellus*, the earth).

Although tellurium and selenium are alike in many respects, they differ in their electrical properties, tellurium being a good conductor of electricity, and selenium, as Berzelius showed, a non-conductor. Knox discovered in 1837 that selenium became a conductor when fused; and Hittorff in 1852 showed that it conducted at ordinary temperatures, when in one of its allotropic forms. When selenium is rapidly cooled from a fused condition, it is a non-conductor. In this its vitreous form it is of a dark-brown color, almost black by reflected light, having an exceedingly brilliant surface. In thin films it is transparent, and appears of a beautiful ruby red by transmitted light. When selenium is cooled from a fused condition with extreme slowness, it presents an entirely different appearance, being of a dull lead-color, and having throughout a granulated or crystalline structure, and looking like a metal. In this form it is perfectly opaque to light even in very thin films. This variety of selenium has long been known as "granular" or "crystalline" selenium, or, as Regnault called it, "metallic" selenium. It was selenium of this kind that Hittorff found to be a conductor of electricity at ordinary temperatures. He also found that its resistance to the passage of an electrical current diminished

continuously by heating up to the point of fusion, and that the resistance suddenly increased in passing from the solid to the liquid condition. It was early discovered that exposure to sunlight hastens the change of selenium from one allotropic form to another; and this observation is significant in the light of recent discoveries.

Although selenium has been known for the last sixty years it has not yet been utilized to any extent in the arts, and it is still considered simply as a chemical curiosity. It is usually supplied in the form of cylindrical bars. These bars are sometimes found to be in the metallic condition; but more usually they are in the vitreous or non-conducting form. It occurred to Willoughby Smith that, on account of the high resistance of crystalline selenium, it might be usefully employed at the shore-end of a submarine cable, in his system of testing and signaling during the process of submersion. Upon experiment, the selenium was found to have all the resistance required—some of the bars employed measuring as much as fourteen hundred megohms—a resistance equivalent to that which would be offered by a telegraph-wire long enough to reach from the earth to the sun! But the resistance was found to be extremely variable. Experiments were made to ascertain the cause of this variability. Mr. May, Mr. Willoughby Smith's assistant, discovered that the resistance was less when the selenium was exposed to light than when it was in the dark.

In order to be certain that temperature had nothing to do with the effect, the selenium was placed in a vessel of water, so that the light had to pass through from one to two inches of water in order to reach the selenium. The approach of a lighted candle was found to be sufficient to cause a marked deflection of the needle of the galvanometer connected with the selenium, and the lighting of a piece of magnesium wire caused the selenium to measure less than half the resistance it did the moment before.

These results were naturally at first received by scientific men with some incredulity, but they were verified by Sale, Draper, Moss, and others. When selenium is exposed to the action of the solar spectrum, the maximum effect is produced, according to Sale, just outside the red end of the spectrum, in a point nearly coincident with the maximum of the heat-rays; but, according to Adams, the maximum effect is produced in the greenish-yellow or most luminous part of the spectrum. Lord Rosse exposed selenium to the action of non-luminous radiations from hot bodies, but could produce no effect; whereas a thermopile under similar circumstances gave abundant indications of a current. He also cut off the heat-rays from luminous bodies by the interposition of liquid solutions, such as alum, between the selenium and the source of light, without affecting the power of the light to reduce the resistance of the selenium; whereas the interposition of these same substances almost completely neutralized the effect upon the thermopile. Adams found that selenium was sensitive to the cold

light of the moon, and Werner Siemens discovered that, in certain extremely sensitive varieties of selenium, heat and light produced opposite effects. In Siemens's experiments special arrangements were made for the purpose of reducing the resistance of the selenium employed. Two fine platinum wires were coiled together in the shape of a double flat spiral in the zigzag shape, and were laid upon a plate of mica so that the disks did not touch one another. A drop of melted selenium was then placed upon the platinum-wire arrangement, and a second sheet of mica was pressed upon the selenium, so as to cause it to spread out and fill the spaces between the wires. Each cell was about the size of a silver dime. The selenium-cells were then placed in a paraffine bath, and exposed for some hours to a temperature of 210° Cent., after which they were allowed to cool with extreme slowness. The results obtained with these cells were very extraordinary; in some cases the resistance of the cells when exposed to light was only one fifteenth of their resistance in the dark.

Without dwelling further upon the researches of others, I may say that the chief information concerning the effect of light upon the conductivity of selenium will be found under the names of Willoughby Smith, Lieutenant Sale, Draper and Moss, Professor W. G. Adams, Lord Rosse, Day, Sabini, Dr. Werner Siemens, and Dr. C. W. Siemens. All observations by these various authors had been made by means of galvanometers; but it occurred to me that the telephone, from its extreme sensitiveness to electrical influences, might be substituted with advantage. Upon consideration of the subject, however, I saw that the experiments could not be conducted in the ordinary way, for the following reason: The law of audibility of the telephone is precisely analogous to the law of electric induction. No effect is produced during the passage of a continuous and steady current. It is only at the moment of change from a stronger to a weaker state, or *vice versa*, that any audible effect is produced, and the amount of effect is exactly proportional to the amount of variation in the current. It was, therefore, evident that the telephone could only respond to the effect produced in selenium at the moment of change from light to darkness, or *vice versa;* and that it would be advisable to intermit the light with great rapidity, so as to produce a succession of changes in the conductivity of the selenium, corresponding in frequency to musical vibrations within the limits of the sense of hearing. For I had often noticed that currents of electricity, so feeble as to produce scarcely any audible effects from a telephone when the circuit was simply opened or closed, caused very perceptible musical sounds when the circuit was rapidly interrupted, and that the higher the pitch of sound the more audible was the effect. I was much struck by the idea of producing sound by the action of light in this way. Upon further consideration it appeared to me that all the audible effects obtained from varieties of electricity could also be produced by variations of light acting upon selenium. I

saw that the effect could be produced at the extreme distance at which selenium would respond to the action of a luminous body, but that this distance could be indefinitely increased by the use of a parallel beam of light, so that we could telephone from one place to another without the necessity of a conducting wire between the transmitter and receiver. It was evidently necessary, in order to reduce this idea to practice, to devise an apparatus to be operated by the voice of a speaker, by which variations could be produced in a parallel beam of light, corresponding to the variations in the air produced by the voice.

I proposed to pass light through a large number of small orifices, which might be of any convenient shape, but were preferably in the form of slits. Two similarly perforated plates were to be employed. One was to be fixed and the other attached to the center of a diaphragm actuated by the voice, so that the vibration of the diaphragm would cause the movable plate to slide to and fro over the surface of the fixed plate, thus alternately enlarging and contracting the free orifices for the passage of light. In this way the voice of a speaker could control the amount of light passed through the perforated plates without completely obstructing its passage. This apparatus was to be placed in the path of a parallel beam of light, and the undulatory beam emerging from the apparatus could be received at some distant place upon a lens, or other apparatus, by means of which it could be condensed upon a sensitive piece of selenium placed in a local circuit with a telephone and galvanic battery. The variations in the light produced by the voice of the speaker should cause corresponding variations in the electrical resistance of the selenium employed: and the telephone in circuit with it should reproduce audibly the tones and articulations of the speaker's voice. I obtained some selenium for the purpose of producing the apparatus shown; but found that its resistance was almost infinitely greater than that of any telephone that had been constructed, and I was unable to obtain any audible effects by the action of light. I believed, however, that the obstacle could be overcome by devising mechanical arrangements for reducing the resistance of the selenium, and by constructing special telephones for the purpose. I felt so much confidence in this that, in a lecture delivered before the Royal Institute of Great Britain, upon the 17th of May, 1878, I announced the possibility of hearing a shadow by interrupting the action of light upon selenium. A few days afterward my ideas upon this subject received a fresh impetus by the announcement made by Mr. Willoughby Smith before the Society of Telegraph Engineers that he had heard the action of a ray of light falling upon a bar of crystalline selenium, by listening to a telephone in circuit with it.

It is not unlikely that the publicity given to the speaking telephone during the last few years may have suggested to many minds in different parts of the world somewhat similar ideas to my own.

Although the idea of producing and reproducing sound by the

action of light, as described above, was an entirely original and independent conception of my own, I recognize the fact that the knowledge necessary for its conception has been disseminated throughout the civilized world, and that the idea may therefore have occurred to many other minds. *The fundamental idea, on which rests the possibility of producing speech by the action of light, is the conception of what may be termed an undulatory beam of light in contradistinction to a merely intermittent one.* By an undulatory beam of light, I mean a beam that shines continuously upon the selenium receiver, but the intensity of which upon that receiver is subject to rapid changes, corresponding to the changes in the vibratory movement of a particle of air during the transmission of a sound of definite quality through the atmosphere. The curve that would graphically represent the changes of light would be similar in shape to that representing the movement of the air. I do not know whether this conception had been clearly realized by "J. F. W.," of Kew, or by Mr. Sargent, of Philadelphia; but to Mr. David Brown, of London, is undoubtedly due the honor of having distinctly and independently formulated the conception, and of having devised apparatus—though of a crude nature—for carrying it into execution. It is greatly due to the genius and perseverance of my friend Mr. Sumner Tainter, of Watertown, Massachusetts, that the problem of producing and reproducing sound by the agency of light has at last been successfully solved.

The first point to which we devoted our attention was the reduction of the resistance of crystalline selenium within manageable limits. The resistance of selenium-cells employed by former experimenters was measured in millions of ohms, and we do not know of any record of a selenium-cell measuring less than 250,000 ohms in the dark. *We have succeeded in producing sensitive selenium-cells measuring only* 300 *ohms in the dark, and* 155 *ohms in the light.* All former experimenters seemed to have used platinum for the conducting part of their selenium-cells, excepting Werner Siemens, who found that iron and copper might be employed. We have also discovered that brass, although chemically acted upon by selenium, forms an excellent and convenient material; indeed, we are inclined to believe that the chemical action between the brass and selenium has contributed to the low resistance of our cells by forming an intimate bond of union between the selenium and brass. We have observed that melted selenium behaves to the other substances as water to a greasy surface, and we are inclined to think that, when selenium is used in connection with metals not chemically acted upon by it, the points of contact between selenium and the metal offer a considerable amount of resistance to the passage of a galvanic current. By using brass we have been enabled to construct a large number of selenium-cells of different forms. The mode of applying the selenium is as follows: The cell is heated, and, when hot enough, a stick of selenium is rubbed

over the surface. In order to acquire conductivity and sensitiveness, the selenium must next undergo a process of annealing.

We simply heat the selenium over a gas-stove and observe its appearance. When the selenium attains a certain temperature, the beautiful reflecting surface becomes dimmed. A cloudiness gradually extends over it, somewhat like the film of moisture produced by breathing upon a mirror. This appearance gradually increases, and the whole surface is soon seen to be in the metallic, granular, or crystalline condition. The cell may then be taken off the stove, and cooled in any suitable way. When the heating process is carried too far, the crystalline selenium is seen to melt. Our best results have been obtained by heating the selenium until it crystallizes, and continuing the heating until signs of melting appear, when the gas is immediately put out. The portions that had melted instantly recrystallize, and the selenium is found upon cooling to be a conductor, and to be sensitive to light. The whole operation occupies only a few minutes. This method has not only the advantage of being expeditious, but it proves that many of the accepted theories on this subject are fallacious. Our new method shows that fusion is unnecessary, that conductivity and sensitiveness can be produced without long heating and slow cooling; and that crystallization takes place during the heating process. We have found that, on removing the source of heat immediately on the appearance of the cloudiness, distinct and separate crystals can be observed under the microscope, which appear like leaden snow-flakes on a ground of ruby red. Upon removing the heat, when crystallization is further advanced, we perceive under the microscope masses of these crystals arranged like basaltic columns standing detached from one another, and at a still higher point of heating the distinct columns are no longer traceable, but the whole mass resembles metallic pudding-stone, with here and there a separate snow-flake, like a fossil, on the surface. Selenium crystals formed during slow cooling after fusion present an entirely different appearance, showing distinct facets.

We have devised about fifty forms of apparatus for varying a beam of light in the manner required, but only a few typical varieties need be shown. The source of light may be controlled, or a steady beam may be modified at any point in its path. The beam may be controlled in many ways. For instance, it may be polarized, and then affected by electrical or magnetic influences in the manner discovered by Faraday and Dr. Ker. The beam of polarized light, instead of being passed through a liquid, may be reflected from the polished pole of an electromagnet. Another method of affecting a beam of light is to pass it through a lens of variable focus. I observe that a lens of this kind has been invented in France by Dr. Cusco, and is fully described in a recent paper in "La Nature"; but Mr. Tainter and I have used such a lens in our experiments for months past. The best and simplest form of

apparatus for producing the effect remains to be described. This consists of a plane mirror of flexible material—such as silvered mica or microscope glass. Against the back of this mirror the speaker's voice is directed. The light reflected from this mirror is thus thrown into vibrations corresponding to those of the diaphragm itself.

In arranging the apparatus for the purpose of reproducing sound at a distance, any powerful source of light may be used, but we have experimented chiefly with sunlight. For this purpose a large beam is concentrated by means of a lens upon the diaphragm-mirror, and, after reflection, is again rendered parallel by means of another lens. The beam is received at a distant station upon a parabolic reflector, in the focus of which is placed a sensitive selenium-cell, connected in a local circuit with a battery and telephone. A large number of trials of this apparatus have been made with the transmitting and receiving instruments so far apart that sounds could not be heard directly through the air. In illustration, I shall describe one of the most recent of these experiments. Mr. Tainter operated the transmitting instrument, which was placed on the top of the Franklin schoolhouse in Washington, and the sensitive receiver was arranged in one of the windows of my laboratory, 1325 L Street, at a distance of two hundred and thirteen metres. Upon placing the telephone to my ear I heard distinctly from the illuminated receiver the words, "Mr. Bell, if you hear what I say, come to the window and wave your hat." In laboratory experiments the transmitting and receiving instruments are necessarily within ear-shot of one another, and we have, therefore, been accustomed to prolong the electric circuit connected with the selenium receiver, so as to place the telephones in another room. By such experiments we have found that articulate speech can be reproduced by the oxyhydrogen light, and even by the light of a kerosene-lamp. The loudest effects obtained from light are produced by rapidly interrupting the beam by the perforated disk. The great advantage of this form of apparatus for experimental work is the noiselessness of its rotation, admitting the close approach of the receiver without interfering with the audibility of the effect heard from the latter; for it will be understood that musical tones are emitted from the receiver when no sound is made at the transmitter. A silent motion thus produces a sound. In this way musical tones have been heard even from the light of a candle. When distant effects are sought another apparatus is used. By placing an opaque screen near the rotating disk the beam can be entirely cut off by a slight motion of the hand, and musical signals, like the dots and dashes of the Morse telegraph code, can thus be produced at the distant receiving station.

We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances. Professor Cross has been kind enough to give me his assist-

ance in conducting these experiments. When a solution of alum, or bisulphide of carbon, is employed, the loudness of the sound produced by the intermittent beam is very slightly diminished; but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this. When the sheet of hard rubber was held near the disk interrupter, the rotation of the disk interrupted what was then an invisible beam, which passed over a space of about twelve feet before it reached the lens, which finally concentrated it upon the selenium-cell. A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium. This could be interrupted at will by placing the hand in the path of the invisible beam. It would be premature, without further experiments, to speculate too much concerning the nature of these invisible rays; but it is difficult to believe that they can be heat-rays, as the effect is produced through two sheets of hard rubber, containing between them a saturated solution of alum. Although effects are produced, as above shown, by forms of radiant energy which are invisible, we have named the apparatus for the production and reproduction of sound in this way, the "photophone," because an ordinary beam of light contains the rays which are operative.

It is a well-known fact that the molecular disturbance produced in a mass of iron by the magnetizing influence of an intermittent electrical current can be observed as sound by placing the ear in close contact with the iron. It occurred to us that the molecular disturbance produced in crystalline selenium by the action of an intermittent beam of light should be audible in a similar manner without the aid of a telephone or battery. Many experiments were made to verify this theory, without definite results. The anomalous behavior of the hard-rubber screen suggested the thought of listening to it also. This experiment was tried with extraordinary success. I held the sheet in close contact with my ear, while a beam of intermittent light was focused upon it by a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard-rubber as a diaphragm, and listening though a hearing-tube. We then tried crystalline selenium in the form of a thin disk, and obtained a similar but less intense effect. The other substances which I enumerated at the beginning of my address were now successively tried in the form of thin disks, and sounds were obtained from all but carbon and thin glass. We found hard rubber to produce a louder sound than any other substance we tried, excepting antimony, and paper and mica to produce the weakest sounds. *On the whole, we feel warranted in announcing as our conclusion that sounds can be produced by the action of a variable light from substances of all kinds, when in the form of thin diaphragms.* We have heard from interrupted sunlight very perceptible musical tunes through tubes of ordinary vulcanized

rubber, of brass, and of wood. These were all the materials at hand in tubular form, and we have had no opportunity since of extending the observations to other substances.

I am extremely glad that I have the opportunity of making the first publication of these researches before a scientific society, for it is from scientific men that my work of the last six years has received its earliest and kindest recognition. I gratefully remember the encouragement which I received from the late Professor Henry at a time when the speaking telephone existed only in theory. Indeed, it is greatly due to the stimulus of his appreciation that the telephone became an accomplished fact. I can not state too highly also the advantage I received in preliminary experiments on sound vibrations in this building from Professor Cross, and near here from my valued friend Dr. Clarence J. Blake. When the public were incredulous of the possibility of electrical speech, the American Academy of Arts and Sciences, the Philosophical Society of Washington, and the Essex Institute of Salem recognized the reality of the results, and honored me by their congratulations. The public interest, I think, was first awakened by the judgment of the very eminent scientific men before whom the telephone was exhibited in Philadelphia, and by the address of Sir William Thomson before the British Association for the Advancement of Science.

At a later period, when even practical telegraphers considered the telephone as a mere scientific toy, Professor John Peirce, Professor Eli W. Blake, Dr. Channing, Mr. Clarke and Mr. Jones, of Providence, Rhode Island, devoted themselves to a series of experiments for the purpose of assisting me in making the telephone of practical utility; and they communicated to me, from time to time, the result of their experiments with a kindness and generosity I can never forget. It is not only pleasant to remember these things and to speak of them, but it is a duty to repeat them, as they give a practical refutation to the oft-repeated stories of the blindness of scientific men to unaccredited novelties, and of their jealousy of unknown inventors who dare to enter the charmed circle of science. I trust that the scientific favor which was so readily accorded to the telephone may be extended by you to this new claimant, the photophone.

EDUCATION AS AN AID TO THE HEALTH OF WOMEN.

By ELIZABETH CUMINGS.

"In education we should endeavor to make a man change from one habit to a better."—THEÆTETUS (PLATO).

THE relation between physical and psychical states is so intimate, and the effects of the latter so nearly simulate disease, that physicians are often led into grave errors in diagnosis and treatment. Nor is this the worst mischief; the secondary stage of psychical excitement may be actual disease, for the nerve-force expended is so much withdrawn from the processes of nutrition and assimilation, and continued morbid action of any of the functions has a tendency to establish organic change. How far education may act as a conserver of psychical, and secondarily of physical health, is therefore a legitimate object of inquiry.

Subject as the female organism is to a periodicity of alternate excitation and depression, the nervous system must respond in a degree to the increased or lowered tension of the veins and arteries. To this physiological cause of emotional excitability are added the effects of habitual in-door life, unhygienic dress, and avocations that are puerile, or that tax the physical strength to the utmost. Instead of correcting the natural tendency, the habits and pursuits of women superimpose upon it an acquired nervous sensibility and irritability, till lack of nerve equilibrium has come to be inherent in civilized women, and Sydenham, generalizing from this point, says, "All women are hysterical"—an assertion that thinking women, especially the mothers of girls, would do well to consider.

The social environment of women is, in its effect, somewhat like the drug mentioned by Dr. Clark in his volume on "Visions," that, taken into the system, paralyzes the nerves of motion, but leaves the nerves of sensation unaffected. An appearance of well-being and content is required of them, at the same time they are exposed, much more than men, to the hurts and wounds that touch what we call the feelings. Without the diversion of work that employs their intellectual faculties, they are constantly tempted to magnify the torments of wounded self-love and the petty griefs that a properly developed nature would not consider. Religion is their only solace, and that incites them to bear their troubles in the martyr spirit, that is, by sheer force of will, an effort that has a markedly anti-vital effect upon the organic functions, rather than with the "sweet reasonableness" which regards harassments as the common lot of all, and therefore determinately turns the attention away from them to higher things.

Though education must for ever work within limits, and can never go beyond the capacity of the individual nature, one can, by strict watchfulness over self, and exercising the will in the required direction, insensibly bring about such a habit of thought, feeling, and action, as he may wish to attain to, his ideal being only a foreshadowing of his own possibilities. To assist one to so train his mind and to furnish him with noble and suitable objects of study is one of the highest offices of a wise education; and that women especially need the help afforded by such training is evidenced by the long list of female patients, suffering from some form of neuropathic disease, that the busy physician carries on his books.

To the uninitiated, hysteria stands for simple foolishness; to the physician, it represents a hydra, hundred-headed, and the parent of yet more serious disorders. There is scarcely a type of disease that it will not simulate. It will even take on the forms of articular rheumatism and spinal disease, and will cause syncope apparently as profound as that induced by organic disease of the heart. It does not limit itself to one attack, for the tendency the automatic apparatus of the body has to repeat its acts will cause the second expression of excitement to be more easily induced, more ungovernable, and more prolonged than the first. And, the hysterical diathesis established, the patient may yield to such seizures till morbid processes set up in the brain and spinal cord. Its effects do not stop with the individual. Lack of voluntary direction of the thoughts and feelings, and yielding to melancholy and depressing passions in the mother, in her resulting in neuropathic states, may exhibit remote effects in her offspring as chorea, epilepsy, or an appetite for spirituous liquors. And it is not too much to say that these diseases and even insanity are often but differing results of a weakening of the nerves and nerve-centers, having ultimately in the mother a psychic cause. For the cure of hysteria and allied complaints physicians declare that skillful mental treatment is better than all the drugs in the pharmacopœia. The recoveries that take place through sympathy, mesmerism, and miracle-mongers, are easily explained when one discovers that diseases, whose remote causes are nervous, often yield instantaneously to appropriate psychical treatment. But better than any remedy is prevention, and, if the mind can exercise a curative influence over an unstrung nervous system, there is no doubt that, by means of proper physical, mental, and moral training, the predisposition to neuropathic complaints, which specialists declare universal in women, may be very nearly extinguished.

A family that came specially under my notice will illustrate the effect of the psychic states of the parent upon the offspring. The father, a full-blooded animal of a man, had a most brutal temper. The mother, a delicate woman of nervous temperament and submissive disposition, used up her nervous energy keeping her husband

pleasant, or enduring his passion. Besides his ungovernable temper, the father had no vices; the mother came of a healthy but somewhat nervous family, who were remarkably religious.

There were five children, three of whom were sons. The eldest inherited his father's temper, was a libertine, and fond of drink. The second son died of delirium tremens; and the third, having squandered his strength and fortune upon women and drink, shot himself. The older daughter, a pale and slender woman of most saintly spirit, gave birth to two children; the first died in infancy; the second lived till the age of puberty, and then went into a rapid consumption. The younger daughter was, during middle life, subject to a periodic insanity, and one of her three children, after suffering from chorea for years, lapsed into idiocy.

Of the family of the oldest son I can only speak with certainty of two. One of his sons had epileptic fits, and one daughter had anger-fits quite like her venerable grandfather, when she would swear with a volubility a trooper might envy. These explosions of temper usually ended in hysterical convulsions. Curious to know more, I inquired of a gentleman, an old acquaintance of the family, what sort of a mother old Mr. Blank had. "Oh, she was a nice old lady when I knew her, though she had spells, and, when she was younger, I've heard them say her spells were awful," was the reply. "What kind of spells?" I asked. "I don't know. When I knew her, anything that crossed her, or made her feel bad, would set her going. She seemed to faint, and would go from one fit to another, till sometimes it was hours afore she was herself. She said she felt as if she was choking, and the doctors gave her no end of 'fæta pills,' but she always had spells till she died." "Were you acquainted with Mrs. Blank's family?" I asked, still curious. "Oh, yes, knew them well," said the old man with an air of marked respect. "They were excellent people. The old lady, Mrs. Blank's mother, was very religious, and at camp-meetings was a master hand at having the power. Oh, she was good, and the right sort."

I do not say that if these mothers had not yielded their self-control, the one to hysterics, the other to religious enthusiasm, all the train of evils that appeared in the family I have described would not have happened; but I am sure I keep within the limits of probability if I assert that determined self-control and self-government on their part would have been markedly influential in producing a corresponding nerve-strength and self-control in their offspring.

The radical defect in the education of girls is, that knowledge, and that of a very superficial sort, instead of the cultivation of the faculties, is made its aim. Regarded by the large majority of educators in a partial light as a means organized for something outside of herself, the girl is simply taught to appear educated. The directing of her mind into a wholesome and self-controlled activity, which is the only means of perfecting the intellectual faculties, is not thought of. Her mind is

made a scrap-bag into which are dropped the dabs of this and that which custom has decreed a young woman should know, and which she and her friends regard very much in the same light as the bows and feathers on her pretty bonnet.

Between the ages of twelve and twenty, the time of all others when her body and its healthful development ought to be carefully looked after, a girl ordinarily receives all the intellectual training she ever has. To do credit to the school and satisfy the mistaken pride of her friends, she is kept in a perpetual hurry, memorizing an incredible number of pages per day. Her chief recreation is a sedate walk, in which dress and behavior have to be considered more than the toning up of her flabby muscles and the oxygenizing of her thin blood. Her chief pleasures are evening entertainments, where her vanity is stimulated to the utmost, and late hours, unhygienic dress, and unwholesome food tax her vitality.

Society emphasizes the education of the boarding-school. To appear well is its sole demand upon young women. Earnestness, an interest in the projects which their founders believe will regenerate the world, all the ebullitions of force characterestic of the young mind that thinks, even an enthusiasm for study, are "bad form" for a young lady in society, and make her suspected of being, at least, "queer." Of course, I speak of ordinary society. There are cultivated congeries in every large city in which more is expected of a girl than mere prettiness. A bright girl who has finished her school-life scarcely knows what to do with herself. Her education was not a preparation for any special work, and, unless she was very fortunate, it did not lay the foundation of proper mental habits. The intellectual in her has been roused, but she has not been taught how to direct it. Some way this force will expend itself: if it can not find a legitimate outlet, it will stimulate the emotions, and find a disastrous activity in them, and too often the "sweet girl-graduate" becomes a sentimental creature, a prey of whims and caprices, capable of an intense but one-sided energy when her enthusiasm is roused, but incapable of any sustained, self-directed effort.

Women rarely find in marriage greater incentives to a real intellectual activity than they find in the boarding-school or in society. Whether the man whose name she takes will be as attractive in middle life as in his youth—whether she will be proud and glad that he is the father of her children—are matters about which the young girl is not taught to think. Domestic economy, as now carried on, is burdensome and full of distasteful and humdrum duties. Having no special aptitudes, not having enough control of her mind to elect to do anything, or to persist in it if she so elect, not knowing how to make the most of what is open to her, unhappiness, real or imaginary, preys upon the average woman to an extent not to be guessed at by a person whose mind is employed.

It is the natural tendency for those powers which are constitutionally the strongest to overrule and weaken the others. If woman is, from physiological causes, more emotional than is good for her, and the habits of civilized life have increased this tendency, if emotional excitement weakens the control which the will ought to exercise over the powers of attention and reflection that stand at the head of intellection, it is the first business of the teacher to employ a girl's faculties as equally as possible—to restrain those which unduly predominate, and exercise the weaker powers.

A girl should be made to understand, from the first, that the education she receives at school is to do for her mind what the scales and exercises do for her fingers in her musical studies; that she is not to study simply to acquire facts, but to get control of her mind. Moreover, she should be taught that it is her duty to look forward to a life-long intellectual activity, so that, when she comes to take full charge of herself, she will direct her mature powers toward some pursuit or line of study which will promote her present or future welfare, and insure to her wholesome mental habits. Especially should her will-power, the force which will, more than any other, make or mar her, receive the most careful training; so that, become adult, she will be able to use it physiologically, and determinately turn from the enemies, wounds, and serious sorrows, that otherwise might induce nervous disease, or drive her into a mad-house, to some one of the many subjects of interest in which the world abounds.

The first mistake in the education of girls, and the one fraught with the saddest results, is made when they are allowed to leave childhood too soon. To keep them little girls as long as possible, and make them, first of all, what George MacDonald calls "blessed little animals," is the first step in the right direction.

The second mistake is, permitting growing girls to sit in the house and study when their transparent cheeks tell of anæmia and lowered vitality. So long as there are branches of knowledge which are admirable training for the mind and can be pursued best out of doors, this mistake is inexcusable. It remains to be seen whether the old methods of education in use in boys' schools are the best for girls: they are best only if they are most physiological. Girls should be treated as they are, not as they might be under improved habits and conditions.

The third mistake is, making the school-life of girls final, when it ought to be a simple preparation for the intellectual life of the adult woman.

A fourth mistake is, withholding a knowledge of the laws to which woman is subject, in her physical and her mental life, her place in nature, and the potential character of her mental states and habits.

ON THE DESTRUCTION OF INFECTIOUS GERMS.

By Dr. A. WERNICH.

THE theory that contagious diseases as well as putrefaction and fermentation are developed and propagated by the agency of organisms allied to the bacteria has been widely accepted, and is supported by the results of recent investigations. It becomes, then, of paramount importance to ascertain the most efficacious means of destroying these organisms.

With this object in view, these researches into the conditions under which bacteria may be destroyed have taken three directions: 1. To test an observation made by Ernst Baumann, that the putrefactive organisms in the course of their action develop carbolic acid, a deadly poison to them, and to inquire whether there are not other poisons to bacteria developed in a similar manner; 2. Investigations prosecuted during the prevalence of the plague to ascertain whether a dry disinfection of clothing and goods could be made effective wholly to destroy the infectious organisms; 3. Having transplanted active infectious organisms from one substance to another to which they are suited, to arrest them in the most rapid stage of their development, destroy them, or cause them to perish.

In order to make the experiments of real value, a sure means must be found of knowing whether the organisms are alive or dead; they may seem dead when they are only passive. The only unfailing test is afforded by the reproductive faculty: when reproduction ceases, and can not be excited, the organisms may be considered dead.

Particular investigators have doubted whether it is possible wholly to destroy these lower organisms. Naegeli* says it can not be fully done without the aid of heat, and even heat is not always equally effective. They are generally more easily destroyed by heat when moist than when dry, but even a boiling heat will not destroy some of them when they are in fluids of a neutral reaction. The more acid the reaction, the less is the degree of heat that is required. The degree of heat required to destroy the germs of infectious diseases is believed to be greater than it is practicable to apply by the dry process to clothing and similar materials. The capacity of many of the organisms to reproduce may, indeed, be destroyed by a more moderate temperature, but a question remains concerning the germs or spores which had been taken up into the materials and were carried away with them. These are believed to have some kind of a coating which enables them to resist what destroys the parent organisms.

In order to test the value of the dry process as applied to infected

* Die niederen Pilze in ihren Beziehungen zu den Infektionskrankheiten und der Gesundheitspflege, s. 201.

clothing, pieces of different clothing materials were impregnated with strong putrefying and bacteria-bearing fluids, then dried slowly, and kept for a long time without protection against external influences. Whenever the smallest piece of one of these materials was put into a suitable fluid, the perturbation invariably took place which is the sure sign of the active multiplication of bacteria. Clothing which had not been impregnated did not excite this perturbation, or only in an insignificant degree. Specimens of the defiled clothing which were placed in a similar solution after they had been exposed for five minutes to a temperature of from 125° to 150° C., or for one or two minutes to a higher temperature, produced no change. The capacity of the bacteria to resist heat varies widely among the different species, and appears to depend largely on the faculty of developing spores. The individuals are killed, but the spores remain vital. The increase of any one kind is limited by the presence of other kinds, with which a struggle for existence has to be maintained.

No increase of bacteria takes place without the presence of a suitable substance to support them. The most favorable of non-nitrogeneous substances is sugar; among nitrogeneous substances the most favorable are the albuminoids; among mineral matters, potash, phosphorus, magnesia, and sulphur. If the supporting substance, even though it is needed in only a minute quantity, is consumed, or if it is present in great excess, a pause in the development, but not the death of the bacteria, takes place. A similar effect is produced by taking away the water, but, when the water is restored, an increase of life again takes place.

The practical object of disinfection should be to go beyond securing a suspension of animation of the bacteria, and to seek to destroy the vitality of the spores. Neither years of dryness, nor months of exposure in foul water, nor repeated drying and moistening, will injure the fertility of these germs.

An excess of water produces a similar effect with desiccation upon the vital conditions of the bacteria. A great dilution of the supporting fluid by the infusion of pure water will in a short time produce a suspension of the process of decomposition. Privation of light has no effect. The operation of electricity has not been enough observed to justify the drawing of any conclusion. The effect of the privation of air has not been fully determined. It was once thought that the development of bacteria could be hindered by the removal of oxygen, but this is doubtful. Oxygen greatly speeds the development, but it can take place without it. Bacteria are not developed in nitrogen, hydrogen, carbonic oxide, carbonic acid, nitrous oxide, and illuminating gas.

The substances which are fatal to the life of the bacteria next demand attention. Among these, the concentrated mineral acids, iodine, bromine, chlorine, the sulphates of copper and zinc, corrosive subli-

mate, benzoic acid and its salts, salicylic and metasalicylic acids, quinia, many aromatic substances, and alcohol, have long been known as such. Carbolic acid is the highest in repute among these poisons; and it is an interesting fact that Mr. E. Baumann has discovered this very substance among the products of the bacterian fermentation to which it is so fatal. Alcohol is another substance similarly associated. The discovery of the curious relations of these two substances gives a new light upon the cause of the spontaneous destruction of bacteria in strongly fermenting fluids, and encourages us to look for other substances having a similar origin and a like action. As evidence of the possession of such properties by any substance, we should require—

1. That substances favorable to the development of bacteria should remain free from them when the substance to be tested is added to them.

2. That active bacteria, when transplanted into a supporting mixture to which a substance supposed to be poisonous to them has been added, should cease to propagate themselves and die out. This may be called the aseptic test.

3. That, when the supposed poison is introduced into a solution swarming with bacteria, all living examples should be killed. This may be called the antiseptic test.

Various aromatic substances, the products of fermentation, were added to a mixture of water and chopped meat at a temperature of 35° C. They proved efficacious in preventing, suspending, or wholly stopping decomposition in the following order, according to the strength of their working:

1. As Preventives of Decomposition:

Indol.....	in a proportion of	1	: 1,000	of the mixture.
Kresol.....	"	2	: 1,000	"
Phenylacetic acid,	"	2·5	: 1,000	"
Carbolic acid	"	5	: 1,000	"

(The working of scatol and hydrocinnamic acid could not be satisfactorily ascertained, on account of the difficulty of dissolving them in water.)

2. As Aseptics—killing transplanted organisms by poisoning the supporting fluid:

Scatol.....	in a proportion of	0·4	: 1,000	of the mixture.
Hydrocinnamic acid	"	0·6	: 1,000	"
Indol.....	"	0·6	: 1,000	"
Kresol.....	"	0·8	: 1,000	"
Phenylacetic acid ..	"	1·2	: 1,000	"
Carbolic acid.....	"	5	: 1,000	"

3. As Antiseptics—wholly destroying all living bacteria:

Scatol, in the proportion of 0·5 : 1,000 of the mixture, in twenty-four hours.

Hydrocinnamic acid, in a proportion of 0·8 : 1,000 of the mixture, in twenty-four hours.

Phenylacetic acid, in a saturated solution (1 : 400), immediately.
Indol, in a saturated solution (1 : 900), in twenty-four hours.
Kresol, in the proportion of 5 : 1,000 of the mixture, in twenty-four hours.
Carbolic acid, in the proportion of 20 : 1,000 of the mixture, immediately.

Two points strike us in this review: first, the difference in the amount of poison required to produce the aseptic and the antiseptic effect; again, it is curious that carbolic acid, the favorite antiseptic, appears to be the weakest on the list. It is at the same time one of the most soluble, while scatol, the most difficult of solution, is the strongest.

If we add the substances we have been examining to a saccharine solution exposed to fermentation, a slackening of the fermenting process will take place, and the different substances will, as before, exhibit their power to delay the process in the following order: scatol, hydrocinnamic acid, indol, phenylacetic acid, kresol, carbolic acid.

These facts seem to justify us in looking for specific disinfectants and prophylactics among the aromatic products of chemical decomposition. They also give a strong air of plausibility to the theory that the bacteria produce, through the chemical changes of which they are the direct cause, the most effective substances that can be used to destroy them. The idea is logically deducible from this theory that the germs of disease finally produce their own destruction by the operation of their growth and development, and helps us to comprehend the cyclical course which is characteristic of most infectious diseases.

POSSIBLE EFFICIENCY OF HEAT-ENGINES.

By Professor WILLIAM A. ANTHONY.

THE theory of thermodynamics, which asserts the equivalence of heat and mechanical work, has now been generally accepted by men of science for thirty years. The equivalence of heat and work is accepted as an established fact by engineers and mechanics, and the mechanical equivalent of heat, as determined by Joule, is made the basis of computations regarding the energy of fuel, etc., by practical men, without a question as to its correctness. But there is one conclusion to which the theory leads, of great practical importance as regards the theory of steam-engines, which does not seem to have been as generally accepted, and yet it is just as firmly established as the fundamental principle of the equivalence of heat and work. A pound of carbon by its combustion in oxygen yields 14,400 heat-units, equal to $14{,}400 \times 772 = 11{,}116{,}800$ foot-pounds of energy. One horse-power should, therefore, be developed by the combustion of about one sixth of a pound of carbon per hour, while our best steam-engines require

about two pounds of coal per hour per horse-power. Hence it is said that the steam-engine is a very inefficient machine, which the genius of the future inventor may improve till a pound of coal is made to yield six, eight, or ten times the power it now gives.

But, while the theory of thermodynamics asserts that the combustion of a pound of carbon yields an amount of heat equivalent to 11,116,800 foot-pounds of energy, it also asserts just as clearly and just as firmly that, under the conditions which exist upon this planet, heat can not be transformed into mechanical effect without wasting a considerable portion of the energy due to it. In other words, if a given quantity of heat be taken from a source, as a steam-boiler, and made to do work by means of any form of engine, a considerable portion of that heat *must, from the very nature of things under existing conditions*, be allowed to pass through the engine and raise the temperature of other bodies to no useful purpose. It is to the discussion upon which this conclusion is based that I propose to devote this article.

In a very valuable essay published in 1824, Carnot furnished us with a conception which is an exceedingly useful one in this investigation. It is that of an engine completely reversible in all its physical and mechanical agencies. A water-motor which could be driven backward by means of some source of power, and would then raise to a given level as much water as it would use from that level to develop the power required to run it backward, would be a reversible engine. It is plainly to be seen that such a motor would be a perfect motor, and also a perfect pump. A reversible heat-engine would be one which, running forward and performing a certain amount of work by means of a given amount of heat derived from a source, would, if run backward by the performance *upon it* of the same amount of work, restore to the source the same amount of heat.

A reversible engine in this sense is, of course, impossible in practice, but the theoretical deductions from the conception are in no way invalidated by this fact. Such a heat-engine would be a perfect engine in the sense that it would produce as much mechanical effect as could be produced by any heat-engine under the same conditions from the same quantity of heat. The proof of this proposition rests upon two assumptions that are supported by all past experience, and may, therefore, be regarded as physical axioms: 1. That a perpetual motion is impossible; 2. That it is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of surrounding objects.

A heat-engine when at work must carry heat from a body of high temperature (the source) to one of low temperature (the refrigerator), and experiment has proved that the amount of heat given to the refrigerator is always less than that taken from the source. Now, let there be two heat-engines, *A* and *B*, of which *B* is reversible, working between the same source and refrigerator. Let each take the same

quantity, H, of heat from the source, and, if possible, let A derive from this heat more work than B. Let h be the quantity of heat carried to the refrigerator, and W the mechanical effect developed by B when running forward. Let W', greater than W by hypothesis, be the mechanical effect developed by A. A may be used to run B backward, and, since B is perfectly reversible, will, in so doing, by the expenditure of the mechanical effect W, take from the refrigerator the amount h, and carry to the source the amount H of heat. The two engines so coupled would then develop the mechanical effect $W' - W$, while no heat would be lost by the source. If A carries to the refrigerator the same quantity of heat that B takes away, the mechanical effect $W' - W$ is developed without any change in external objects, without any consumption of energy. This would constitute a perpetual motion, which, by the first axiom, is impossible. If A transfers to the refrigerator less heat than B takes away, the refrigerator will grow colder and colder, and, since for the purposes of this discussion all other bodies may be assumed to be at the same temperature as the source, this will present the case of a machine producing mechanical effect while taking heat from the coldest of surrounding bodies. This is contrary to the second axiom. Therefore, A can not do more work under the conditions named than B. The reversible engine, then, derives as much mechanical effect from a given amount of heat as can be derived by *any heat-engine whatever* working between the same temperatures.

It follows further that all reversible engines working between the same source and refrigerator, and taking from the source the same amount of heat, must yield the same mechanical effect; in other words, must have the same efficiency. No matter what the working substance, or in what way heat is made to yield mechanical effect, so long as the process is completely reversible, the same amount of mechanical effect will always be derived from the same heat taken from the source.

It may be well to emphasize a little the first conclusion, that no heat-engine whatever can be more efficient than a reversible engine. If the reasoning is correct, no form of heat-engine, whether using air, or gas, or a condensable vapor, or a liquid, or a solid, as the working substance, or using thermo-electric currents, or any other means of converting heat into mechanical effect, can be more efficient than any one of the reversible engines. There is no escaping this conclusion except through the perpetual motion, or the derivation of mechanical effect from the heat of a body already cold. It has been sometimes claimed that the latter alternative was no impossibility, that the expansion of a compressed gas, the expansion of a gas into a vacuum, or the diffusion of one gas into another, may perform work at the expense of its own heat, while being cooled down to a lower temperature than surrounding bodies. But to compress the gas, or produce

the vacuum, or separate the gases preparatory to diffusion, requires an expenditure of energy at least equal to the mechanical effect to be derived.

Since the reversible engine is as efficient as any heat-engine, and since all reversible engines of whatever construction and whatever the working substance have the same efficiency, it is allowable, in discussing the question as to the amount of mechanical effect derivable under given conditions from a given amount of heat, to assume any form of reversible engine, using any working substance which may be most convenient. And it makes no difference whether the engine assumed be practically possible, so long as we know the properties of the working substance well enough to determine its action under the assumed conditions. Sir W. Thomson, before 1851, assuming Carnot's engine with air as the working substance, furnished us with a very complete discussion of this question. The properties of air in relation to heat are very simple. Heat expands and cold contracts it with great uniformity. Compression heats and expansion cools it according to a well-known law. The effects of any change of volume or of temperature in the cylinder of an engine can, therefore, be exactly predicted.

Suppose a given mass of air to be compressed and the heat developed by compression removed, so that its temperature remains constant. The pressure exerted by it will increase, as shown graphically in the annexed diagram, where *O a*, measured on the horizontal axis *O x*, represents the initial volume, and *a e* perpendicular to *O x* represents the pressure exerted at that volume. *O b*, *O c*, and *O d*, represent other volumes, and *b f*, *c g*, *d h*, the corresponding pressures. The curved line *e f g h*, drawn through the extremities of the perpendiculars, represents to the eye the relation between volume and pressure *when temperature is constant.* It is called an *isothermal line.* Now, suppose the air to be compressed without loss or gain of heat. It is warmed by compression, and the rise of temperature causes it to exert a greater pressure. If, then, the substance be at the same initial volume, pressure, and temperature as before, and it be compressed to the volume *O b* without loss of heat, the pressure exerted will be *b m* greater than *b f*. Similarly the pressure *c n* will correspond to the volume *O c*, and *d o* to *O d*. The line *l m n o*, which shows the relation between volume and pressure *when no heat enters nor escapes*, is called an *adiabatic line.*

Fig. I.

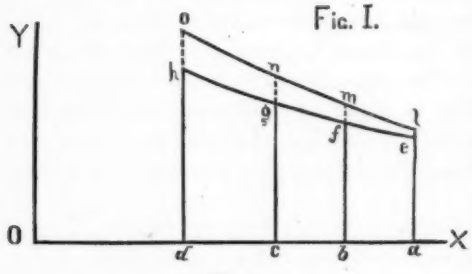


Fig. 1.

Carnot's engine consists of a cylinder having no outlet nor inlet, with an air-tight piston inclosing a mass of air which changes in volume with the movements of the piston. The piston and sides of the cylinder are supposed to be perfect non-conductors, while the bottom of the cylinder is a perfect conductor of heat. The engine has a source of heat and a refrigerator, whose temperatures are supposed to remain absolutely constant whether parting with or receiving heat. There is also a non-conducting stand, on which, if the cylinder be placed, no heat can enter or escape from it, however much the air within it may change in temperature. In the working of the engine there are four operations, as follows:

First Operation.—The air is supposed to be at the temperature of the refrigerator, which may be designated by t, and to have a volume represented by $O\ a$, and pressure represented by $a\ A$ (Fig. 2). The cylinder is supposed to stand upon its non-conducting support. The piston is now depressed, and, since no heat can escape, the air rises in temperature. The compression continues till the temperature of the air becomes that of the source, which we designate by T. The rise in pressure will be represented by the *adiabatic* line $A\ B$. Let $O\ b$ represent the volume and $B\ b$ the pressure at the end of the operation. It is plain that work must have been done to compress the air, equal to the space swept through by the piston multiplied by the mean pressure; but this is represented by the area of the figure $A\ B\ b\ a$.

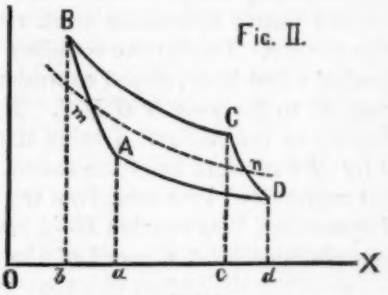


FIG. II.

FIG. 2.

Second Operation.—The cylinder is placed upon the source of heat and the piston allowed to rise, being forced upward by the pressure of the air. The bottom of the cylinder being a perfect conductor, heat will enter so rapidly as to maintain the temperature of the air while it expands. The pressure therefore falls, as indicated by the *isothermal line* $B\ C$. Let this operation continue until an amount of heat H is taken from the source, and suppose $O\ c$ to represent the volume and $c\ C$ the pressure of the air at that time. It will be seen that during this operation work represented by the area $B\ C\ c\ b$ will have been done *by the air.*

Third Operation.—The cylinder is returned to its non-conducting support. The upward stroke of the piston continues, and the air expands without receiving heat, until its temperature falls to that of the refrigerator, that is, to the temperature that it had at the beginning of the first operation. The fall of pressure is represented by the *adiabatic* $C\ D$, and work represented by the area $C\ D\ d\ c$ is done *by the air.*

Fourth Operation.—The cylinder is placed upon the refrigerator, the piston caused to descend, and the air compressed until its initial volume is reached. Since the bottom of the cylinder and the refrigerator are supposed to be perfect conductors, the heat generated by the compression will escape to the refrigerator, and the temperature of the air will remain constant. The air is now in the same condition as regards temperature, volume, and pressure, as at the beginning of the first operation. The *isothermal line*, which represents the rise of pressure during the last operation, must, therefore, pass through the starting-point *A*. During this operation work represented by the area *A D d a* must be done upon the air, *and a certain amount of heat—all that generated by compressing the air—must be given up to the refrigerator.*

It will be noticed that, during the second and third operations, work represented by the area *B C D d b is done by the air*, and during the first and fourth operations work represented by *B A D d b is done upon the air.* During the complete cycle of operations, therefore, mechanical effect is developed equivalent to the difference between these areas, or to the area *B C D A*. This figure is, in fact, the indicator diagram of the engine. During the second operation, heat represented by *H* was taken from the source, and during the fourth operation heat represented by *h* was given to the refrigerator. During the cycle of operations, heat equal to $H-h$ has disappeared, and, since the working substance is at the end of the cycle in precisely the same condition as at the beginning, this heat must be the equivalent of the mechanical effect developed, and the efficiency of the engine is $\frac{H-h}{H}$

But it is easily shown that this cycle of operations is a completely reversible cycle. For suppose the substance at its initial volume *O a*, pressure *A a*, and temperature *t*. Place the cylinder on the refrigerator, and allow the air to expand to the volume *A d*. The same isotherm *A D* that represented the rise in pressure in the reverse operation will now represent the fall, and the same heat *h* that was before given to the refrigerator will now be taken from it. Now let the cylinder be placed upon its non-conducting support and the piston descend till the volume becomes *O c*. Since no heat escapes, the rise of pressure will be represented by the adiabatic *D C*, and the temperature will rise by the same amount as it fell during the expansion from *c* to *d*, that is, from *t*, the temperature of the refrigerator, to *T*, that of the source. Now, let the cylinder be placed upon the source, and the descent of the piston continue till the volume of the air becomes *O b*, the temperature remains that of the source, the isotherm *C B* represents the rise in pressure, and heat is given to the source precisely equal to the amount taken from it during the expansion from *b* to *c* in the direct working of the engine. Now let the cylinder be placed upon its non-conducting support, and the piston rise till the volume becomes *O a*.

Since no heat can enter, the temperature will fall to t, and the pressure to $A\,a$. It is easy to show that, during this reverse cycle, an amount of mechanical energy represented by $A\,B\,C\,D$ has been expended, and it is seen that heat equal to h has been taken from the refrigerator, and heat equal to H given to the source. The engine is, therefore, a perfectly reversible engine in the sense before defined, and it has already been seen that no other heat-engine of whatever construction, steam, gas, hot air, thermo-electric, or whatever it may be, working between the same temperatures, could develop more mechanical effect from the heat H taken from the source. In other words, any heat-engine working between the temperatures T and t, and taking from the source the amount H of heat, must transfer to the refrigerator an amount of heat at least equal to h, the amount given up by our reversible engine under the same conditions. It remains to be seen what relation this bears to the heat taken from the source.

Experiment proves that the lower the temperature the smaller is h, and it is evident that if the temperature of the refrigerator had been lower the isotherm $A\,D$ would have been $O\,X$. The area $A\,B\,C\,D$ would then be greater, and, since this represents the work done by the engine in one revolution, it is seen that this is greater the lower the temperature of the refrigerator. It appears, then, that the proportion of the heat taken from the source which can be converted into mechanical effect, is greater as the temperature of the refrigerator is lower, and the question arises, how low must this temperature be in order that the whole of the heat may be so converted. Perhaps the best way of approaching this question is by Sir W. Thomson's absolute scale of temperature. This may be defined as a scale upon which the temperatures of any two bodies are to each other as the heat received is to the heat rejected by a reversible heat-engine using one of the bodies as a source and the other as a refrigerator. That is, if T and t are the temperatures upon the absolute scale of our source and refrigerator, $T : t :: H : h$, or $T-t : T=H-h : H$.

Let T be the temperature of boiling water, and t that of melting ice, and let $T-t = 180°$, as in the Fahrenheit scale. From the properties of air we know that if it is used as the working substance of a reversible engine, with a source at the temperature of boiling water and a refrigerator at the temperature of melting ice, $H-h : H :: 100 : 373$ nearly. Hence

$$180 : T :: 100 : 373$$
$$T = 671{\cdot}4$$
$$\text{and } t = 491{\cdot}4.$$

Any other temperatures may be easily determined. Suppose $B\,C$ (Fig. 2) be the isotherm corresponding to the temperature of boiling water, $A\,D$ that corresponding to that of melting ice, and $m\,n$ an isotherm corresponding to some intermediate temperature, that marked 100° on the Fahrenheit scale, for instance, whose temperature t' upon

the absolute scale we wish to determine. We have as above $T-t : T :: H-h : H$, and $T-t' : T :: H-h' : h'$, if h' is the heat rejected at the temperature t'. Hence $T-t : T-t' :: H-h : H-h'$. But $H-h$ is the heat converted into work by an engine working between the temperatures T and t, and is proportional to the area $B\,C\,D\,A$. Also $H-h'$ is the heat converted into work by an engine working between the temperatures T and t', and is proportional to the area $B\,C\,m\,n$. Therefore $T-t : T-t' ::$ area $B\,C\,D\,A$: area $B\,C\,m\,n$; or $180° : T-t' ::$ area $B\,C\,D\,A$: area $B\,C\,m\,n$.

Having the data for constructing the isothermal and adiabatic lines, the areas $B\,C\,D\,A$ and $B\,C\,m\,n$ can be computed, and hence t' determined. The divisions of an absolute scale so constructed are found to correspond very closely with the divisions of the air-thermometer, and to differ but little from the divisions of the Fahrenheit scale. We are led, then, to the conclusion that to convert all the energy of a given amount of heat into mechanical effect, a refrigerator at a temperature of 491 Fahrenheit degrees below the melting-point of ice, or 459° below zero Fahr., is necessary.

Let us recapitulate briefly the points of this argument.

1. It is impossible for any heat-engine, of whatever construction, to convert into mechanical effect a larger proportion of the heat derived from a given source than can be done under the same conditions by a reversible engine. This proposition can not be denied without involving a denial of two physical axioms which are founded upon the results of all past experience, viz.: That the perpetual motion is impossible, and that "it is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of surrounding objects."

2. That all reversible engines, whatever the working substance, have the same efficiency; that is, taking from the source the same quantity of heat H, they will transfer to the refrigerator the same quantity h, and convert into mechanical effect the same quantity $H-h$. Hence whatever results are derived from a discussion of any one form of reversible engine will be true of all others.

3. If a scale of temperature be constructed such that the temperature of the source is to the temperature of the refrigerator of a reversible engine as the heat derived from the source is to the heat given to the refrigerator, the scale divisions will differ but little from the divisions of the scales in common use. The efficiency of an engine will then be $\frac{T-t}{T} = 1 - \frac{t}{T}$.

4. Upon such a scale, if there are, as in the Fahrenheit scale, 180° between the freezing and the boiling points of water, the former point would be numbered 491·4 and the latter 671·4. The pos-

sible efficiency of an engine working between these two temperatures would therefore be $\frac{671{\cdot}4-491{\cdot}4}{671{\cdot}4}$, 27 per cent. nearly.

Heat-engines are often spoken of as very inefficient machines, because they transform into mechanical effect but a small proportion of the heat used. The inefficiency is not so much the fault of the machine as of the conditions under which it is worked. Consider the case of a condensing engine with a boiler pressure of 45 pounds and a vacuum of 25 inches of mercury. The temperature of the source is here about 294° and of the refrigerator 140° Fahr. The possible efficiency under these conditions is about 20 per cent., that is, a *perfect* engine working between those temperatures could give in mechanical effect no more than one fifth the energy of the heat. The best steam-engines would, under these circumstances, give one-horse power for something less than two pounds of coal per hour. This is an efficiency of 10 or 12 per cent., or more than half the possible efficiency. The engine, as a machine, is not so very imperfect. In speaking of the engine, I of course include the boiler as a part of the machine. Any great improvement must come from an increased range of temperature between the source and refrigerator. The temperature of the refrigerator can not well be lower than the general temperature of surrounding objects, and there are great practical difficulties in the way of a very high temperature of the source. Suppose an engine could be worked with a source at a temperature of 1250° of the absolute scale, or nearly 800° Fahr., and a refrigerator at 500° of the absolute scale, or nearly 40° Fahr., the possible efficiency would be $1-\frac{500}{1250}$, or only 60 per cent. It appears, then, that there is not much hope that any large percentage of the energy of heat can, by any practical means, be converted into mechanical effect. But are we, for this reason, to continue wasting the energy of fuel as it is wasted now? Is there no other way in which the energy of chemical separation of carbon from oxygen can be converted into mechanical effect except by first converting it into heat? Why may not the union of carbon with oxygen be made to generate electric currents instead of heat? Electric energies have been made that convert into mechanical effect 60 to 70 per cent. of the energy of the electric current, and a much higher efficiency might, no doubt, be obtained. Already something has been done toward the generation of electric currents by the union of carbon and oxygen; but, so far, no means has been discovered by which such a union can be effected, except at a high temperature, and this involves a great waste of energy in the form of heat. A discovery that would enable us to convert the energy of fuel into electric currents directly and completely would revolutionize, not only the methods of obtaining power, but the methods of obtaining light and distributing heat as well. I have shown elsewhere that, if a Brayton oil-engine is used to

drive a dynamo-electric machine producing the electric light, more than twice as much light will be developed as would be obtained if the oil that runs the engine were burned in the ordinary coal-oil lamps. How much greater would be the economy if the energy of the oil could be converted directly into the energy of the electric current!

For warming buildings, the furnace would become an electric generator, from which wires, instead of pipes for steam or hot air, would lead to the rooms to be heated, when, by interposing a suitable resistance, the energy of the current would be converted into heat. The probability of being able to convert the energy due to combustion of fuel into electric instead of heat energy may be very small; but it is at least a possibility; that is, there is no known reason in the nature of things why it can not be done, while it is demonstrated that the whole of the energy of heat can not be converted into mechanical effect, except by means of a refrigerator at a temperature of nearly 500° below that at which water freezes—a temperature which has never yet been reached, and which it is impossible to obtain with our present surroundings, except by an expenditure of energy equal to that which would be gained.

SKETCH OF GEORGE BOOLE.

"AND pray who is George Boole, that he should be pictured and sketched in 'The Popular Science Monthly'? We thought this department was to be devoted to scientific celebrities, chiefly contemporaneous; but who is this Boole?"

Such will probably be the exclamation of nine of our readers out of ten; but the tenth, or more safely the hundredth, reader will know that George Boole was a man of a very high order of genius, a profound and most original thinker of this century, who will be known in future by his contributions to mathematical and logical science. Yet he can never be widely *known*, for his work was so recondite that those who can properly appreciate it will always be but very few. We gather the following particulars of his life from the last edition of the "Encyclopædia Britannica":

GEORGE BOOLE was born in Lincoln, on the 2d of November, 1815. His father was a tradesman of limited means, but of studious character and active mind. Being especially interested in mathematical science, the father gave his son early instruction in the rudiments of the science he was so greatly to advance; but it is remarkable that the extraordinary mathematical powers of George Boole did not manifest themselves in early life, as was the case with Zerah Colburn, Babbage, Pascal, Leibnitz, and Saunderson. The classical languages formed at first the favorite subject of his studies. It was not until he had at-

tained his seventeenth year that he attacked the higher mathematics, and his progress was much retarded by the want of efficient help.

When about sixteen years of age he became assistant master in a private school in Doncaster, and he maintained himself to the end of his life in one grade or other of the scholastic profession. Few distinguished men, indeed, have had a less eventful career. Almost the only changes which can be called events are his successful establishment of a school at Lincoln; its removal to Waddington; his appointment, in 1849, as Professor of Mathematics in Queen's College, Cork; and his marriage, in 1855, to Miss Mary Everest.

His works are comprised in about fifty scattered articles and a few separate and individual publications. Only two systematic treatises on mathematical subjects were completed by Boole. These were a "Treatise on Differential Equations," which appeared in 1859, and was followed, next year, by a "Treatise on the Calculus of Finite Differences," designed to serve as a sequel to its predecessor. In the sixteenth and seventeenth chapters of the former work he lays down a lucid exposition of the symbolic method, the bold and skillful employment of which led to his chief discoveries.

Boole was one of the most eminent of those who perceived that the symbols of operation could be separated from those of quantity and treated as distinct objects of calculation. His principal characteristic was perfect confidence in any result obtained by the treatment of symbols in accordance with their primary laws and conditions, and an almost unrivaled skill and power in tracing out these results.

During the last few years of his life, Boole was constantly engaged in extending his researches, with the object of producing a second edition of his "Differential Equations," much more complete than the first edition; and part of his last vacation was spent in arduous study in the libraries of the Royal Society and the British Museum, for the purpose of acquiring a complete knowledge of the less accessible original memoirs on the subject. It must be always a matter of regret that this new edition was never completed. Even the manuscripts left at his death were so incomplete that Mr. Todhunter, into whose hands they were put, as literary executor, found it impossible to use them in the publication of a second edition of the original treatise, and printed them, as a supplementary volume, in 1865.

Profound and important as were Boole's discoveries in pure mathematics, his writings on logic may be considered as still more original. With the exception of De Morgan, he was probably the first English mathematician since the time of Wallis (1616–1703) who had also written upon logic; and his wholly novel views of logical method were due to the same profound confidence in symbolic reasoning to which he had successfully trusted in mathematical investigation. From the preface to his "Mathematical Analysis of Logic," printed as a separate tract in 1847, we learn that speculations concerning a cal-

culus of reasoning had, at different times, occupied Boole's thoughts, but it was not till the spring of 1847 that a memorable logical controversy led him to put his ideas into a definite form. He afterward regarded this pamphlet as a hasty and imperfect exposition of his logical system, and desired that his much larger work, "An Investigation of the Laws of Thought," etc. (1854), should alone be considered as containing a mature statement of his views.

This is Boole's greatest work, and is an attempt to apply the symbols and operations of mathematics to logic and the laws of thinking. The object of the work, as stated by himself, is "to investigate the fundamental laws of those operations of the mind by which reasoning is performed; to give expression to them in the symbolical language of a calculus, and upon this foundation to establish the science of logic and construct its method; to make that method itself the basis of a general method for the application of the mathematical doctrine of probabilities; and, finally, to collect from the various elements of truth, brought to view in the course of these inquiries, some probable intimations concerning the nature and constitution of the human mind."

Of this work Professor Todhunter, in the preface to his "History of the Theory of Probabilities," speaks as "marvelous"; and, in similar language, Professor W. Stanley Jevons speaks of it as "one of the most marvelous and admirable pieces of reasoning ever put together."

It is often supposed that mathematicians are deficient in judgment and knowledge of other matters. In Boole this was not the case; for, though he published little except his mathematical and logical works, his acquaintance with general literature was wide and deep. Dante was his favorite poet, and he preferred the "Paradiso" to the "Inferno." The metaphysics of Aristotle, the ethics of Spinoza, the philosophical works of Cicero, and works of a kindred character, were frequent subjects of his study.

The personal character of Boole inspired all his friends with the deepest esteem. He was marked by the modesty of true genius, and his life was given to the single-minded pursuit of truth. Though he received a royal medal for his memoir ("Philosophical Transactions of the Royal Society," 1844), and the honorary degree of LL. D. from the University of Dublin, it may be said that he neither sought nor received the ordinary rewards to which his discoveries entitled him.

"On the 8th of December, 1864, in the full vigor of his intellectual powers," says W. Stanley Jevons, in his tribute to his friend's life and genius, "George Boole died of an attack of fever, ending in suffusion on the lungs."

The mathematical and logical works of Boole are by far too abstruse to admit of their being used as text-books in schools of even the highest grades; but as works of reference they are invaluable to advanced students and the special cultivators of pure mathematics and the profounder problems of logic.

EDITOR'S TABLE.

THE BOSTON SCIENTIFIC MEETING.

THE twenty-ninth annual meeting of the American Association for the Advancement of Science, which began on the 25th of August, in Boston, was in every respect a most successful affair, and will be memorable both in the history of the Association and to all who had the pleasure of attending it. A large amount of excellent scientific work was accomplished, as shown by the fact that no less than two hundred and eighty original scientific papers were entered for reading at the different sections. Many of these were able and valuable contributions to independent research, and they all evinced a strong and healthy activity of the spirit of investigation. The meeting was the largest ever held by this body. The session opened on Wednesday, and by the succeeding Tuesday evening nine hundred and seventy-nine persons were registered, and of these five hundred and ninety-five were new members. As a happy and novel consequence, there will now be some surplus funds for the Association to use in aid of important researches.

To say that Boston did justice to the occasion is not enough, for justice is a thing of degrees. Boston did splendid justice—redeemed every expectation, which is saying a good deal, and did that ample honor to science both in public and in private which science well deserves. Whatever could be done to facilitate the work of the Association and to make it pleasant for all its members was done. The hospitalities were cordial and profuse. The corporations of Boston and Cambridge and wealthy private citizens gave entertainments to the Association, which were luxurious, elegant, and in excellent taste. Free excursions were provided to all points of interest in the vicinity, and, when work was through, a large lot were sent off to the White Mountains in charge of the Apalachian Club. Every detail of preparation had been carefully attended to by numerous efficient committees, and the completeness of the smooth-working arrangements excited the admiration of all. It is hard to suit everybody, but we must say that this feat was for once accomplished. Even where idiosyncrasies were jostled, only smiles were elicited. Nine hundred and fifteen persons accepted the city's invitation to take a trip down the bay in a commodious steamer. A generous collation was provided in the cabin, and when the guests had partaken of it, as they passed to the deck above, each gentleman was presented with an envelope on which was stamped, "The City of Boston welcomes the American Association for the Advancement of Science." Each envelope contained three choice cigars, and we mention the fact merely to say that the most fanatical non-smokers benignly accepted the graceful attention, and either kept their little prize as a souvenir of the occasion, or enjoyed the cigars by presenting them to their favored friends. Whatever was interesting in Boston in the shape of institutions and attractive features was open to the members, and multitudes of them profited by the opportunity. Invitations were cordially extended to visit the American Academy of Arts and Sciences, the Massachusetts Historical Society, the Boston Society of Natural History, the Society of Decorative Art, the Warren Museum of Natural History, the Boston Public Library, the Athenæum Library, the commandant of the Charlestown Navy Yard, the

Metric Bureau, Tufts College, the Watertown, Arsenal, the Old South, and many other places of interest to strangers.

It has been objected that too much time is generally spent at these meetings in social enjoyment; but it is not to be forgotten that this is a cardinal object of the organization. It is both possible and desirable that in future years the management will be so improved that the social element without being impaired will be so regulated as to economize time and offer the least hindrance to the legitimate and solid work of the society. But the Association grew out of a social need which is more urgent, perhaps, in this country than in any other. The organization of the British Association for the Advancement of Science, half a century ago, was not only a very important movement in giving efficient direction to scientific labor, but it was an inevitable result of the growth of scattered activities which required to be brought into coöperative relations. It was found that scientific observers, experimenters, and discoverers are not mere eccentric and infatuated devotees, content to pass their lives in the cloistered seclusion of laboratories and observatories, but that they are normal human beings with social sympathies and necessities, who require to know each other and to be brought into relations of freer intercourse with the people. The British Association was formed for the promotion of the interests of science by systematizing the work of research, and by bringing large numbers of scientific men together annually for several days, and it was made migratory that its public influence might become effective in all parts of the country. The advantages of this associated action were real and important, and it was proved that the time had fully come to enter upon it. A new impulse was given to original study; there were new accessions to the ranks of scientific students, scientific work became more effective and efficient, and the people extended to it increasing encouragement and a more hearty and liberal support.

So successful was this plan of operations devised and carried out by the English scientists, that it has been imitated in different nations, and with the same satisfactory results. In this country such a project was both more necessary and more difficult. The scientific men were here widely distributed over a continent, and generally worked alone in the colleges, so that they very rarely met their brethren to compare notes and gain the benefits of mutual criticism. In England it was different. London was a great center of resources, a sort of scientific world of itself, while the country is so small that the metropolis is readily accessible to everybody. In the United States there was no such commanding center of scientific influence, and the distances and the expenses of travel were so great that scientific professors, generally living upon small salaries, could hardly afford to travel, even if there had been any great central headquarters to visit. The adoption of the English plan of a movable scientific association, to hold its meetings in different and widely separated localities, met the requirements of our scientific men to a much greater degree than it did the English.

This kind of association, therefore, does a more important work here than anywhere else. There are obstacles to the advance of science which are more refractory in the United States than anywhere else. Institutions for training scientific men are neither so numerous nor so thorough as in England and on the Continent. Material interests are more absorbing, and the effect of our "popular intelligence" is that subjects and questions foreign to science have an intense hold and a predominant control over the public mind. There is no way to stem these tenden-

cies that is so adequate and practical as this annual gathering of scientific men in the different cities, and under the conditions secured by the American Association.

The problem of its success is one of social dynamics. There are resistances to be overcome in the shape of difficulties in bringing scientific men together from distant points, and of public apathy toward the interests of science. The American Association has been checked by these impediments, but it has made headway in spite of them. There has been a varying success at its different meetings, but on the whole the most encouraging progress, which is signalized by the fact that the last meeting has been the most successful and satisfactory of all.

We print the able and interesting address of the retiring President, Dr. George F. Barker. It is a model discourse of its class, reporting the present state of knowledge upon a subject of grave interest, and in a style suited to all readers of general intelligence.

Dr. Lewis H. Morgan, of Rochester, presided with an easy dignity over the general sessions of the meeting, and he could not fail to be gratified with the increasing interest shown in the ethnological studies to which he has so long devoted himself, and of which he is now the most eminent American representative. The section dealing with these subjects had many instructive papers and a full attendance throughout the meeting.

Professor George J. Brush, of New Haven, was elected the next President, and will preside over the meeting to be held at Cincinnati, beginning August 17, 1881.

THE NEW PHOTOPHONE.

THE most striking result brought out at the late meeting of the American Association had reference to the relations of sound and light, and was due to the joint labors of Mr. A. Graham Bell and Mr. Sumner Tainter, of Boston. The luminous ray, whether of sunlight or from an artificial source, was shown to be capable of transmitting articulate sounds, as the wire transmits them in the case of the telephone. The mechanical combination by which this effect is produced is called the *photophone*. We print in full Mr. Bell's paper describing the principle and mechanism of the contrivance, and the experiments by which it was elucidated and brought into shape. The metal selenium, discovered in the early part of the century, but hitherto of no practical use, here comes into prominence. It was known to have curious properties, shifting into allotropic forms with the most contrasted characters, and changing its electrical relations in a remarkable manner under the influence of light. Under the arrangements of the inventors, rays of light give rise to sound by impinging upon a surface of selenium—sounds which are audible through the telephone either as continuous musical notes of different pitches, or as vocal communications. Though it is said that light produces the effect, yet this is not strictly true; for a thick plate of India-rubber, if interposed in the path of the acting beam, intercepts all the light but still permits the passage of the radiant force which produces the sound. It is some dark ray accompanying the light proper that does the work. The experimenters have found also that other substances share with selenium the property here made available, though in a less degree. We thus have another step in the rapid progress of molecular physics and the marvelous interaction of forces which is sure to stimulate experimental inquiry, though whether it will confound past conclusions and clear up past mysteries it is impossible to say. And equally impossible is it to say whether the photophone will turn out to be of any practical use. But it is certainly

unsafe to deny it. The telephone is but a thing of yesterday, and was at first supposed to be only a curious plaything. But already "there's millions in it." How far it is developed as a business is shown by the fact that a convention of twenty-one companies meets at Niagara to look after the interests of this new and rapidly extending means of intercommunication.

LITERARY NOTICES.

THE BRAIN AS AN ORGAN OF MIND. By H. CHARLTON BASTIAN, M. D., F. R. S. D. Appleton & Co. Pp. 708. Price, $2.50.

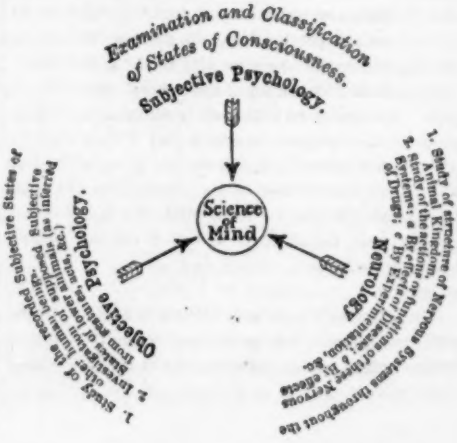
DR. BASTIAN'S new book is one of great value and importance. The knowledge it gives is universal in its claims, and of moment to everybody. It should be forthwith introduced as a manual into all colleges, high schools, and normal schools in the country. Not to be made a matter of ordinary mechanical recitations, but that its subject may arrest attention and rouse interest, and be lodged in the minds of students in connection with observations and experiments that will give reality to the knowledge acquired.

As often illustrated in the pages of this magazine, we know nothing of mind except as an organic manifestation. Throughout the entire scale of animate nature, intelligence is an endowment of a nervous mechanism; and the gradations of intelligence correspond to and depend upon gradations in the structure of the nervous system. The laws of mind have their basis in this material substratum, and mental operations are conditioned upon physiological processes. The wonderful apparatus of sensation, distributed over the periphery of the body and relating the individual to all that is outward, and the still more wonderful organ of consciousness and mental power—the great cerebral center—are material structures, and the psychical effects which they produce are accompaniments of material molecular change. We think, and feel, and remember, and imagine, and carry on all the processes of reasoning through the corporeal activities of the brain as the great center of nervous operations. We are born high or low in the intellectual grade according to the properties of this mechanism; and these properties are variable in an almost infinite degree. We get the benefit of a perfected stock through generations of cultivation, or we inherit incapacity through generations of neglect, the results in both cases being embodied in the nervous organism. It is therefore impossible to get at the science of mind so as to grasp the laws of mental growth, or rationally to carry on the work of mental cultivation without a knowledge of the vital mechanism by which all mind is displayed. No book, therefore, can be fitter for collegiate study or as a guide in the work of education than a well-prepared treatise on the physiological basis of intelligence. There are many valuable publications upon this subject, but we have seen none among them that promises to be so satisfactory as a text-book as Dr. Bastian's work on "The Brain as an Organ of Mind."

We have often discussed this subject, but its great importance, and the disposition to ignore it, nay, the actual dread of it on the part of many well-meaning people, make it necessary that there should be no relaxation in the efforts to diffuse correct ideas concerning it. For thousands of years the mind has been regarded as an entity belonging to an immaterial sphere, in some mysterious way brought into relation with the material order, but still so separated from it, and so far above it, that mental problems must be studied alone, and only by their own peculiar methods. This is the metaphysical point of view which was universally pursued before science arose, and is still the prevailing method of regarding mental phenomena. But it is a partial method, dealing only with one side of the subject, and lacking the foundation that is necessary to give scientific clearness and validity to the study of mind. Modern science has given a new extension to mental studies, but it has at the same time greatly complicated them, and introduced a factor requiring laborious and progressive elucidation; and the consequence is, that many prefer the older and easier method, regardless of the character of the results. Multitudes also shrink with a kind of horror from

the association of anything material with so pure and spiritual a study as that of mind. Said an eminent spiritual-minded teacher to the writer, "I hate that word 'organization' worse than any other in the language." It is needless to say that this attitude of mind is as far as possible from scientific, and has not truth for its object. Yet the prejudice is powerful, both in paralyzing the minds of individuals and in hindering educational improvement. All the colleges and high schools in the country make loud professions of the thoroughness of their work, and they are every one occupied in dealing with the human brain; but, if there has ever been a book on the brain introduced into one of them for systematic study, we have never heard of it, and we have not been unheedful of the subject. Years are given to the most unspeakable rubbish—to subjects of study so vacant of all use that their continuance is becoming an open scandal; while a knowledge of the laws of the great organ of thought, that "institution of God" which gives law to the mental world, is passed by as unworthy of any serious attention. If the graduates from our colleges, normal schools, academies, and high schools, as they come forth, diploma in hand, were questioned as to the structure, powers, and organic relations of the brain they profess to have been cultivating, would it not be found that their ignorance is quite as great as that of those who have never had the advantage of a higher education? The subject has been too long and too grossly neglected, and we are glad of the appearance of Dr. Bastian's book, as it will take away all excuse for further neglect on the score that there is no suitable manual of the subject adapted to general use.

We can give no detailed account of this work within the limits of a notice, and only desire to convey a general idea of its method of treating the subject. There are three modes of arriving at a knowledge of the laws of mind: In the first place, each man has a source of this knowledge within himself. He carries on the mental operations in his own consciousness, and can observe and analyze them there according to his practice and skill in introspection. This source of acquaintance with mental operations is immediate and direct, and of the highest authority for the individual; but it is incomplete and liable greatly to mislead from this cause. This is known as the subjective field of inquiry. But it is possible to know something about the minds of other people in a different way. We know by experience that mind has its outward expressions, and these expressions in others, which are of the most varied kind, become indications to us of their mental states. In the same manner we acquire a knowledge of the mental activities and capacities of the lower animals, which manifest in various degrees the endowment of intelligence. What we observe without, in this way, constitutes the sphere of objective psychology. But there is another capital source of a knowledge of mind, which comes from investigating the organic structures and functions by which it is manifested in all its grades and forms. We here study the brain and nervous system, tracing its evolution from the lowest germ to the highest development, and tracing the growth of the brain of man from its embryonic rudiments to the mature and perfected structure. This branch of the study of the mind is marked off from the others by applying to it the term neurology. The following diagram, from Dr. Bastian's chapter entitled "The Scope of Mind," is designed to show how all these departments of study require to be combined in order to produce a true science of mind:



Our author does not attempt in this volume to give us a complete exposition of mental science. He has, indeed, to deal with subjective psychology and with objective psychology, but he treats these aspects of mental study in relation to the third great mental division, the organic conditions which are the latest results of scientific investigation. From this point of view, the whole subject assumes a new interest, and becomes far more practical than by the previous partial modes of examination. Dr. Bastian has done all that it was possible to do to bring his topic within the range of popular apprehension. Much of his volume will be read with pleasure and profit by all classes; but much of it also requires study and a mastery of its indispensable technicalities. The work can not be put to its proper and highest use unless the objects of which it treats are to a certain extent made real to the mind of the student. Diagrams, of which there are a great profusion, and finely executed, are helps, but they can not be put in the place of the objects they represent without a sacrifice of the first condition of true scientific knowledge—the bringing of the mind into contact with the real things. But there is happily no serious impediment to this manner of study. The brains and nervous parts of animals are to be had anywhere in abundance and in great variety. It is by no means expected that the reader or student will be able to verify the whole course of illustration in this volume, nor is it at all necessary. But it is necessary that he should become acquainted with the rudiments of the exposition by direct observation, so that he will have clear and precise ideas in relation to its subject matter, such as will conduce to a genuine understanding of the general subject. We commend this work especially to teachers, and venture to affirm that if they will form classes in it, not with a view to the slavish acquisition of its contents, but to master portions of it so that the rest may be read intelligently, it will prove invaluable both as a means and an end of education.

Dr. Bastian's book was written as a contribution to the "International Scientific Series"; but, as the author found it impossible to do justice to the subject within the limits prescribed for those works, his volume has been separately issued in this country.

DEGENERATION: A CHAPTER IN DARWINISM. By Professor E. RAY LANKESTER, F. R. S. London: Macmillan & Co. 1880. Pp. 75. Price, 75 cents.

NATURAL selection may have operated to produce present organic forms in three different ways. Organisms may have been elaborated in structure with a growth in variety and complexity of the conditions to which they were subjected; they may have remained for a long period without any change, when the conditions have been immobile; or, the conditions having become simpler, they may have lost in structure. In accounting for present forms, naturalists have given little heed to the last of these processes, but have endeavored to explain nearly all cases (except those of the parasites, which are generally recognized as degenerate forms) on the basis of the first two processes. In the discourse before the British Association, which forms this volume, Professor Lankester takes issue with this view, and argues in support of the thesis that degeneration is an important process in organic evolution. He contends that many problems are helped to a solution by this hypothesis, which without it are hopelessly obscure, and that the evidence in its favor is of a high order. His argument is based upon the evidence furnished by the changes through which the egg passes in its development into the young creature. As is well known, the forms through which it passes are those that belonged to its ancestors, and these are reached in the order, there is good reason to believe, in which they were acquired by these ancestors. This "recapitulative development" is often very imperfect, many characteristics are obscured or obliterated, but none appear that did not at some time belong to the creature's progenitors. Where these changes are distinct, then, the pedigree of an organism can be traced by them with certainty. A number of cases of degeneration are cited by Professor Lankester, the two most important being the ship's barnacle and the ascidian phallusia. In the case of the barnacle, the egg gives rise to an actively swim-

ming nauplius, which after a time fastens its head to a piece of wood and adopts an immobile life. It then loses its organs of touch and sight and power of locomotion, its legs being used simply to bring any floating particles of food to its mouth. A more remarkable case of loss of structure is that of the ascidian phallusia, one of a class of sea-animals found incrusting rocks, etc., on the sea-bottom, the individuals being often joined together, forming a plant-like mass. The individual is a tough, leathery mass, shaped somewhat like a bottle, with an opening at each end, through which water continually passes, and possessed of little internal structure. Most of the young of ascidians differ widely from their parents, that of the phallusia the most markedly. The egg of this gives rise to a tadpole which bears a close resemblance in outward form and internal structure to the tadpole of the common frog, both possessing the four distinctive structures of the vertebrata. But, while the tadpole of the frog ascends in the scale of organization, that of the ascidian descends to a form in which its origin is unrecognizable. Without the recapitulative development in this case of the ascidian, Professor Lankester avers that no naturalist would have suspected that it belonged to the vertebrata, and, as this recapitulation is so frequently wanting, and when it exists is often shorn of its "most important part," it is not safe to set limits to the possible occurrence of degeneration. Many forms now supposed to be improvements upon their ancestors may, upon further investigation, be shown to be degenerate. The conditions that he thinks predispose to degeneration are parasitism, fixity or immobility, vegetative nutrition, and excessive reduction of size; and when, therefore, organisms are characterized by these habits or peculiarities, degeneration may be suspected. While Professor Lankester's discussion is confined to zoölogy, he recognizes the bearing of the hypothesis upon evolution in general—upon man and the arts perfected by him. The general conclusion he reaches is, that while the former universal belief that man and other creatures had degenerated from a previous perfect condition is untrue, the contrary opinion, that development has been a continuous progress from lower forms, is also untrue. The truth lies between the two; there have been both progress and retrogression, and both movements will probably take place in the future as in the past. The constant cultivation of those things that make for progress will alone secure any race from the possibility of degeneration. Full illustrations accompany the text to afford a ready comparison of the forms pointed out. Notes on the relation of the doctrine of development to the theological doctrine of a soul, and on some further cases of degeneration, are appended to the text.

THE OBELISK AND FREEMASONRY, ACCORDING TO THE DISCOVERIES OF BELZONI AND COMMANDER GORRINGE. By JOHN A. WEISSE, M. D. With Illustrations and with the Hieroglyphics of the American and English Obelisks, and Translations into English, by Dr. S. Birch. New York: J. W. Bouton, 706 Broadway. 1880. Pp. 178. Price, $2.00.

THE newspapers last spring reported that stones bearing masonic emblems had been discovered in the foundations of the Egyptian obelisk that has since been brought to this city. A description of the emblems by Grand-Master Zola, of the Grand Lodge of Egypt, and a letter from Consul Farman, at Alexandria, confirming the fact that discoveries had been made, were also published. Dr. Weisse, who fully believes in the antiquity of masonry, was presented by Mrs. Belzoni, widow of the celebrated Egyptian traveler, in 1850, with manuscripts, drawings, etc., assuming to show that an institution similar to freemasonry existed in Egypt before pyramids and obelisks. All of these evidences, with other matter and illustrations bearing upon the same point, have been combined in this work, which is curious and interesting if not historical and scientific.

ANNUAL REPORT UPON THE SURVEYS OF NORTHERN AND NORTHWESTERN LAKES AND THE MISSISSIPPI RIVER, IN CHARGE OF C. B. COMSTOCK, MAJOR OF ENGINEERS, etc.; being Appendix MM of the Annual Report of the Chief of Engineers for 1879. Washington: Government Printing-Office. Pp. 80.

THE report shows progress in the triangulation of Lake Erie, the triangulation connecting Lake Erie with Lake Michigan,

the erection of stations for the triangulation running south from Chicago, and water-level observations on the lakes. Progress has also been made on the survey of the Mississippi River. The longitudes and latitudes of Louisiana, Missouri, Rock Island, Illinois, and Red Wing, Minnesota, have been determined. Several of the coast-charts of Lakes Ontario and Erie, and charts of the Mississippi south of Memphis, have been completed. Among the important facts noticed is the observation of sand-waves in the Mississippi at Helena, which in water from thirteen to thirty feet deep are moving down the river at an average rate of eighteen feet a day. They had an average length, counting from crest to crest, of about three hundred and thirty feet, an extreme length of about five hundred feet, and an average height of about five feet and an extreme height of eight feet from valley to crest. The existence of sand-waves of so large dimensions, and moving with such a velocity, does not seem to have been observed before on the lower Mississippi.

THE MICROSCOPIST'S ANNUAL FOR 1879, No. 1. New York: The Industrial Publication Company. 1880. Pp. 48. Price, 25 cents.

THE object of this publication is to keep microscopists informed of what is going on that is of particular interest to them. It contains a list of microscopical societies in the United States and of a few foreign societies, and the names, alphabetically arranged, of manufacturers and dealers in microscopes, objects, apparatus, etc., in the United States and Europe, with other practical information.

THE NORTH AMERICAN ENTOMOLOGIST. July, 1879, to April, 1880. A. R. GROTE, Editor. Buffalo, N. Y.: Reinecke, Zesch & Baltz. Monthly. Pp. 8. Price, $2.00 a year.

THIS magazine was begun with the purpose of presenting original articles of value both to the specialist and the agriculturist on the subject of North American insects and notices of current entomological literature. The articles in the ten numbers before us show the results of careful research, present new facts, and are many of them well illustrated.

HEVEENOID: THE RUBBER OF THE FUTURE. By HENRY A. MOTT, Jr., Ph. D., etc. New York: Trow's Printing Company. Pp. 13.

HEVEENOID is India-rubber combined with camphor and vulcanized by sulphur. It was invented by Henry Gerner, and is offered as a new product to supplant the common soft and hard vulcanized India-rubber, over which it is claimed to possess many points of superiority. These points are set forth, and the process of manufacture is described, in the pamphlet.

THE ORIENTAL AND BIBLICAL JOURNAL. Edited by Rev. STEPHEN D. PEET. Chicago: Jameson & Morse. 1880. Pp. 52. Quarterly. Price, $2.50 a year.

THE object of this magazine is to give the results of the latest researches in all the Oriental lands and in the countries of classical history. It is intended also to embrace many subjects of a more general character, such as the manners and customs of all nations, their traditions, mythologies, religious notions, language, and literature. In the present number, Professor T. O. Paine describes two Osirids of ancient Egypt owned by persons in the United States; and, in an article on "The Antiquity of Sacred Writings in the Valley of the Euphrates," Mr. O. D. Miller seeks to prove that the materials of the Book of Genesis were derived through Abraham from the same originals whence the oldest Chaldean writings came.

THE THOUSAND ISLANDS OF THE RIVER ST. LAWRENCE; with Descriptions of their Scenery, as given by Travelers from Different Countries, at Various Periods, and Historical Notices of Events with which they are associated. Edited by FRANKLYN B. HOUGH. Syracuse, N. Y.: Davis, Bardeen & Co. 1879. Pp. 307. Price, $1.25.

THE title gives as clear an idea of the character of this book as can be gained from a fuller description. The historical sketch is ample and satisfactory. The travelers' descriptions date from Charlevoix, in 1721, are favorable and unfavorable, and are quoted from a host of authors of various nationalities. They are followed by a chapter on the poetical associations, and by notices of the camp-meeting parks, geology, names, and other features of the islands.

DIAGRAM OF THE PROGRESS OF THE ANTHRACITE COAL-TRADE OF PENNSYLVANIA, WITH STATISTICAL TABLES, etc. By the Messrs. SHEAFER, Engineers of Mines, Pottsville, Pa. Chart.

THIS diagram is designed to accompany a paper which was read before the American Association for the Advancement of Science, at its meeting for 1879. It shows the gradual development of the trade, and the dates of the opening of new avenues to the market. An accompanying diagram shows the estimated quantity of anthracite coal in the three several coal-fields of Pennsylvania, and the relative amount of waste and quantity mined. Another cut represents a cross-section in the southern anthracite coal-field of Pennsylvania. The tables show a variety of facts bearing on the subject, in Pennsylvania, the United States, and the world.

AMERICAN HEALTH PRIMERS.—THE SUMMER AND ITS DISEASES. By JAMES C. WILSON, M. D.—WINTER AND ITS DANGERS. By HAMILTON OSGOOD, M. D. — THE THROAT AND THE VOICE. By J. SOLIS COHEN, M. D.—BRAIN-WORK AND OVERWORK. By Dr. H. C. WOOD. Philadelphia: Presley Blakiston. 1879 and 1880. Pp. 126 to 160. Price, 50 cents each.

THESE primers are prepared for the purpose of diffusing as widely and cheaply as possible a knowledge of the elementary facts of preventive medicine and the bearings and applications of the latest and best researches in medical and hygienic science, and of teaching people how to take care of themselves, their children, etc. They are written from an American point of view, with especial reference to our climate, sanitary legislation, and modes of life. The whole series is under the general supervision of Dr. W. W. Keen. The first volume, whose title is given above, considers each of the common special diseases of summer, and the means of preventing and curing them, and has a chapter on the skin in summer and its maladies. The second work enforces the need of suitable clothing, care in bathing, ample provision of pure fresh air, and out-of-door exercise in winter. In the third volume, the structure, care, and several diseases of the throat are treated of in separate chapters, and a second part is devoted to the voice and its cultivation. In the last primer of the list are discussed the subjects of the "Causes of Nervous Trouble," "Work," "Rest in Labor," "Rest in Recreation" and "Rest in Sleep."

MEMOIRS OF THE SCIENCE DEPARTMENT, UNIVERSITY OF TOKIO, JAPAN. Vol. II. ON MINING AND MINES IN JAPAN. By C. NETTO, M. E., Professor of Mining and Metallurgy, University of Tokio. Published by the University, Tokio. 2539 (1879). Pp. 56, with Plates.

THIS work comprises the substance of a lecture which was delivered before a German society, and has been translated into English to make it more accessible to Japanese students. The useful minerals in Japan, ranked nearly according to their importance, are coal, copper, silver, gold, iron, kaolin, petroleum, sulphur, lead, antimony, tin, cobalt, quicksilver, marble, jasper, agate, amber, graphite. The processes of mining and reducing the ores are described, after which is given a summary of the Japanese mining law, and a review of the measures that have been adopted or are contemplated by the Government for the encouragement of mining. Modern methods are shown to have been adopted in several of the mines, and their introduction has been attended with increase of production. The Government at present carries on a number of mines, into which it has introduced modern model works, partly for the sake of setting a good example to private owners. It is its policy, however, to surrender its establishments when they have become well organized, to be worked by private citizens. Six large plates give representations of the tools used by the Japanese in mining.

THE AMERICAN JOURNAL OF PHILOLOGY. Edited by BASIL GILDERSLEEVE, Professor of Greek in Johns Hopkins University. Vol. I., No. 2. May, 1880. Baltimore: the Editor. New York and London: Macmillan & Co. Pp. 126. Four numbers a year. Subscription price, $3.00.

THIS journal is open to original contributions in all departments of philology, gives condensed reports of current philological work, summaries of the chief articles in the

principal philological journals of Europe, and keeps watch over the fragmentary and occasional literature to which the isolated American scholar seldom has full access. The present number has an article on "Recent Investigations of Grimm's Law," by H. C. G. Brandt; three articles on Greek and Latin subjects, by F. D. Allen, C. D. Morris, and M. W. Humphreys; and two on French subjects, by B. F. O'Connor and Samuel Garner.

FIRST ANNUAL REPORT OF THE DEPARTMENT OF STATISTICS AND GEOLOGY OF THE STATE OF INDIANA, 1879, TO THE GOVERNOR. Indianapolis: Douglass & Carlon. Pp. 515.

THIS report embraces ninety-nine tables of agricultural, mercantile, manufacturing, financial, and other statistics, by counties and townships. The report of the Indiana State Health Commission, which is embodied with the general report, embraces papers on "Health in the Schoolroom," by President Moss, of the State University; "Topography and Climate," by Professor Campbell, of Wabash College; "Decomposing Organic Matter, Sewage, and Drainage," by Dr. G. W. Burton; "The Influence of Popular Customs, Habits, and Heredity, on Public Health and Morals," by Dr. J. W. Hervey; and "The Influence of Geology upon Local Diseases," by E. T. Cox, late State Geologist.

MACMILLAN & Co. have in press, for publication in the early fall, a book which is likely to be of value to the medical profession, and of advantage to the general public; it is entitled "Food for Invalids," and is written by Dr. J. Milner Fothergill, of London, and Dr. H. C. Wood, of Philadelphia.

HENRY GEORGE'S "Progress and Poverty" has been translated into German by F. Gutschon, and will be shortly published by Stude, of Berlin.

PUBLICATIONS RECEIVED.

Report to the Trustees of the "James Lick Trust" of Observations made on Mount Hamilton, with reference to the Location of Lick Observatory. By S. W. Burnham. Illustrated. Chicago: Knight & Leonard. 1880. Pp. 32.

Quarterly Report of the Chief of the Bureau of Statistics relative to Imports and Exports, Immigration, and Navigation of the United States, for the Three Months ending March 31, 1880. Washington: Government Printing-Office. 1880. Pp. 190.

Adirondack Survey: Report on Iron Deposits, etc. By George Chahoon. Albany: Weed, Parsons & Co. 1880. Pp. 16.

Electricity: Elementary Guide-Book for Practical Experiments and Self-Study. By Professor Curt W. Meyer. With Illustrations. New York. 1880. Pp. 25. 25 cents.

The Claims of Science, for its own Sake, upon the Medical Profession. Address, by Professor John W. Mallet, M. D., of the University of Virginia. Baltimore: J. W. Borst & Co. 1880. Pp. 28.

Medical Science in Conflict with Materialism. By Eugene Grissom, M. D., LL. D. Wilmington, N. C.: Jackson & Bell. 1880. Pp. 31.

Notes on the Flowering of Saxifraga Sarmentosa. By Professor J. E. Todd. Reprint from "American Naturalist." Illustrated. Pp. 6.

Ophthalmic Operations, with Remarks on After-Treatment. By A. Sibley Campbell, M. D. Augusta, Ga. Pp. 35.

The Laterite of the Indian Peninsula. By W. J. McGee. Reprint from "The Geological Magazine." Pp. 4.

Annual Report of the Board of Directors of the Chicago Astronomical Society, with Report of the Director of the Dearborn Observatory. Illustrated. Chicago: Knight & Leonard. 1880. Pp. 16.

Review of Stratigraphical Geology of Eastern Ohio. By Professor Edward Orton. Columbus: Nevins & Myers. 1880. Pp. 33.

American Natural Cement. By F. O. Norton. Illustrated. Pp. 18.

Circulars of Information of the Bureau of Education. No. 2. 1880. Washington: Government Printing-Office. 1880. Pp. 111.

Introduction to the Study of Mortuary Customs among the North American Indians. By Dr. H. C. Yarrow. Washington: Government Printing-Office. 1880. Pp. 114.

What to do First in Accidents or Poisoning. By Charles W. Dalles, M. D. Illustrated. Philadelphia: Presley Blakiston. 1880. Pp. 70. 50 cents.

The Skin in Health and Disease. By L. Duncan Bulkley, M. D. Philadelphia: Presley Blakiston. 1880. Pp. 148. 50 cents.

Manual of Hydraulic Mining for the Use of the Practical Miner. By T. F. Van Wagener, E. M. New York: D. Van Nostrand. 1880. Pp. 93.

The Authorship of the Fourth Gospel: External Evidences. By Ezra Abbott, D. D., LL. D. Boston: George H. Ellis. 1880. Pp. 104. 75 cents.

Qualitative Chemical Analysis: a Guide in the Practical Study of Chemistry and in the Work of Analysis. By Silas H. Douglas, M. A., M. D., and Albert B. Prescott, M. D., F. C. S. With a Study of Oxidation and Reduction by Otis Coe Johnson, M. A. New York: D. Van Nostrand. 1880. Pp. 305.

Deep-Sea Sounding and Dredging: a Description and Discussion of the Methods and Appliances used on Board the Coast and Geodetic Survey Steamer "Blake." By Charles D. Sigsbee, Lieutenant Commander, U. S. N. Illustrated. Washington: Government Printing-Office. 1880. Pp. 200.

POPULAR MISCELLANY.

The Cotton-Worm Investigation.—The Commission for the investigation of the cotton-worm has been organized under Professor C. V. Riley as chief, and its members have been stationed at different points in the South to make local examinations. Professor J. P. Stillé, of Alabama, and Judge J. W. Jones, will represent the Commission in Texas; Professor R. W. Jones, Dr. E. H. Anderson, and Mr. Lawrence Johnson, in Mississippi; Mr. H. G. Hubbard, of Detroit, Michigan, in Florida; Professor Barnard, of Cornell University, will fully study those parts of Louisiana and Mississippi which were neglected in 1878 and 1879 on account of yellow fever; Judge J. F. Bailey, and Mr. James Roane, chemist, will make a special series of experiments in Alabama; Professor J. E. Willet will make experiments in Georgia to test the usefulness of fungus-germs in the destruction of the worm. Maps are to be prepared by Professor Smith, of the State University of Alabama, showing the different cotton regions classified with reference to the hibernation of the insect. Professor Riley, besides having the general superintendence of the work, and advising with his assistants, will collect information and make other preparations for introducing the cultivation of the *pyrethrum*, which he believes will afford a safe antidote for the worm.

Changes in the Natural Vegetation at San Francisco.—Dr. Herman Behr has published a description of the changes that have taken place in the vegetation of the San Francisco peninsula within the last thirty years. The region was originally distinguished by three types of landscape: the sand-dunes and hills, covered with live-oak, ceanothus, horse-chestnut, and wild cherry, ferns, and common herbs; an open tract of grassy plains, with trees in the ravines, and flowering plants; and a marshy plain, with boggy prairie, covered with a varied growth of bushes and herbaceous plants. Now, the first-mentioned type of vegetation, the *chaparral*, exists still in a few spots; the second, that of the pasture-land, is to be met with still, wherever the distance from the city is considerable enough to protect native vegetation; but the third type has entirely disappeared. In the course of the extension of the city, Australian evergreens and conifers form the Sierra have largely replaced the original trees. "Parallel with this artificial immigration of Australian arborescents, goes on an herbaceous immigration from Europe and Africa." The thistle (*Silybum marianum* of the Mediterranean region) has invaded both California and South Australia, and, wherever it gets a hold of the soil, all native vegetation disappears. The tree-lupines particularly suffer from its encroachment. Another weed, *Cotula coronopifolia*, a native of South Africa, well known in Mediterranean Europe, and which has invaded South Australia, does the same work in moist ground that is begun by silybum in more arid tracts. It "has transformed the varied aquatic vegetation of the different places infested by itself into one monotonous green mass with yellow buttons." Dr. Behr regards as significant that these two plants are congenital and belong to one of the most modern orders, of which fossil specimens are found in only the most recent formations, and to which he attributes the vigor of youth.

The Physiological Effects of Tea and Coffee.—Professor Albert B. Prescott, M. D., of the University of Michigan, has published a paper, in "The Physician and Surgeon," on the physiological effects of coffee as compared with those of tea, concerning which the authorities are confusing and little is really known. Inasmuch as the chief constituents of both substances are capable of determination, we ought to be able to declare something, he thinks, as to what there is in common between a medium cup of coffee and an average cup of tea. The effects of tea and coffee, he continues, must be mainly due to the properties and proportions of the alkaloids, tannin, volatile oils, and ordinary food-substances contained in them. As to the alkaloids, no differences have been established between theine and caffeine. In average quantity, the alkaloid forms about one per cent. of the raw coffee-berry, and two or three per cent. of tea. A little of it, but very little, is lost in roasting coffee. The greater

part of it is extracted in the beverage as usually prepared, both of tea and coffee. A pound of tea usually furnishes from three to five times as many pints of beverage as are obtained from a pound of coffee, but the ways of preparing and the estimates are so different that nothing exact can be determined on this point. As a whole, the proportions for given volumes of beverage can not be declared habitually much larger in the one than in the other; if there is any difference, the coffee-beverage is likely to be the stronger. The tannins are tannic acid in both substances—boheic and gallic acid in tea, and caffeic acid in coffee, all astringents. Tea contains, according to the analyses relied upon by Dr. Prescott, from six to twenty per cent., an average of twelve per cent. of tannins; some other estimates make the percentage very much larger. This large amount is, however, by no means all dissolved in the ordinary preparation of tea as a beverage. No tannin was dissolved in steeping for five minutes six out of eleven specimens of different qualities of tea at the Michigan University, and the percentage of the other five specimens was not large, the average percentage of the whole being only 0·08. After thirty minutes' steeping, the quantity of tannin dissolved varied from 1·09 to 4·50 per cent., the average being 2·49, and was in no case equal to half the amount contained in the tea. A larger quantity of tannin was extracted in other experiments in which the tea had been macerated at ordinary temperature before boiling. The tannin in coffee-berry, by all reports, is not more than one third the quantity of that in tea-leaves, and may be considerably less. Six specimens of coffee were steeped for five minutes without yielding any tannin; two of them showed a trace of tannin after ten minutes' steeping; after twenty minutes', five of the specimens showed from 0·01 to 0·25; after thirty minutes', the proportion of tannin given up varied from 0·09 to 1·80, the average being 0·83. Other analyses show that tea contains an average of 0·206 grains, coffee 0·055 grains, of tannin to the fluid ounce of the beverage in use. These results leave no doubt that the tea we drink contains at least four or five times as much tannin as the coffee we drink, and that the tea yields only a small proportion of its large quantity of tannin, after from five to ten minutes of steeping. If tea or coffee is to be administered, as in any case of poisoning by alkaloids, tea, well steeped, is to be chosen as the better antidote for the precipitation of alkaloids, and equally potent as a stimulant. The essential oil of tea is a very small but distinct constituent, the most important factor in determining its market value. It is conjectured to be an organic stimulant, and may promote perspiration. Coffee, in the unroasted berry, has no volatile oil; but, in roasting, an agreeable essential oil is developed, the effects of which are not known, but which may cause the digestive disturbance sometimes ascribed to coffee-drinking. Of nutrient substances, tea contains pectin, gum, legumine, and indeterminate matters, yielding, in all, to boiling water about thirty-two per cent. of its weight. Coffee contains, after roasting, from one to two per cent. of glucose, ten to twelve per cent. of fat, nearly as much legumine, and a little gum, and yields thirty-five per cent. to water. "It is not unlikely," Dr. Prescott concludes, "that these food-substances, as modified by roasting, disagree with the digestion of many persons. This is, let me submit, a not improbable explanation of the class of injurious effects of coffee-drinking, when the substitution of tea-drinking gives relief. The powerful nerve-stimulant, caffeine, as we have seen, is obtained in about as large doses from tea as from coffee. The caffeine of both these beverages undoubtedly produces injury to the nervous system in many cases; but, when coffee causes palpitation, sleeplessness, etc., not resulting from tea, let me suggest that some attention be paid to the digestive organs."

Water in Disease.—Dr. S. G. Webber, in the "Archives of Medicine" for August, attributes a considerable value to water as a preventive and a remedy of disease, and opposes the abstinence from drinking at meals, advocated by many, as injurious. Among patients who have come under Dr. Webber's care affected with "symptoms of an undefined character, a vague unrest and disquiet showing itself by discomfort or even pain, sometimes in one place, sometimes in another," with constipation and an unhealthy

hue of the skin, he has found that many were accustomed to take less than the usual average quantity of drink. In such cases he would prescribe an increased quantity of drink, with beneficial effects in increased perspiration, and the decrease or disappearance of the unpleasant symptoms. The waste of tissue-changes in the system passes into the blood, and leaves the system only in solution. This, Dr. Webber maintains, can not take place unless enough water is taken. Further, "water taken with the food favors digestion; when taken into the stomach a part is absorbed by the gastric vessels, carrying with it the soluble constituents of the food. So much as is not immediately absorbed assists in softening and breaking up the larger particles of food, and thus aids in the gastric digestion by facilitating the action of the gastric fluids." It also makes it easier to keep the bowels regular. In estimating the quantity of water to be taken daily, we should remember that water is excreted by the lungs and skin, as well as by the kidneys, and that much food contains water. Hence the amount required must vary slightly with the activity of the skin and the character of the food. Dalton states that the average amount is about fifty-two ounces, or 3·38 pints, or the equivalent of eight or nine coffee-cups of drink.

Temperature of the Breath.—Mr. R. E. Dudgeon has been trying some experiments on the temperature of the breath, and infers from the results that it is considerably higher than has generally been stated, and that it is variable. First, on rising in the morning, having ascertained the temperature of his body as shown by the thermometer in the axilla and mouth to be normal—about 98½°—he wrapped the thermometer tightly in a silk handkerchief and breathed upon it. In five minutes it indicated 106·2. At 7 P. M., after a brief walking exercise, and when he had eaten nothing but a spoonful of boiled rice, and drunk only half a glass of water and a mouthful of ginger-beer, his breath raised the mercury to 107°. Immediately after a dinner at which only water was drunk, a temperature of 108° was shown. At other times the thermometer would not rise, under apparently the same conditions, higher than 102° to 105°. He can suggest no way of accounting for these indications otherwise than by admitting that they show the actual temperature of the breath as it issues from the lungs. "If so," says Mr. Dudgeon, "it is by the breath that the system gets rid of its superfluous caloric." The experiments seem to show that the temperature obtained from the breath is higher when the surrounding air is warm than when it is cold, indicating possibly that more heat is passed off by the breath when less can escape from the general surface of the body.

The Ancient Outlet of Lake Bonneville.—The name of "Lake Bonneville" has been applied to a great body of water which formerly covered the desert basins of Utah, of which the most conspicuous vestiges are its shore-lines. It is known from them that the ancient water-surface was more than ten times as great as that of the Great Salt Lake, and that the ancient level of the water was about one thousand feet above the modern level. The point at which the waters of this lake were discharged is still undetermined. Mr. G. K. Gilbert maintained, in the "American Journal of Science" for April, 1878, that the point of overflow was Red Rock Pass, Idaho, at the north end of Cache Valley; that the discharging stream descended through Marsh Valley, and thence continuously to the Pacific Ocean; and that, flowing over soft material at first, it gradually excavated at the pass a channel more than three hundred feet deep, and lowered the level of the lake by the same amount. Dr. A. C. Peale controverted Mr. Gilbert's conclusion in a subsequent number of the "Journal," and held that the original altitude of the Red Rock Pass was considerably below the highest level of Lake Bonneville; that the original shore-line exists in Marsh Valley, at the north end of the pass, as it does in Cache Valley at the south; and that the real point of discharge, when the water stood at the Bonneville level, was about forty-five miles north of Red Rock Pass. Mr. Gilbert has, within a few months, revisited Marsh Valley and Red Rock Pass, and other points near the former supposed outlet of the lake, and gives in the May number of the "Journal"

his reasons, derived from his later observations, for adhering to his former conclusion. He assumes to determine the character of the body of water which has occupied a given spot, whether it was a stream or a lake, from the nature of the terraces left in the valley. Thus there are stream-terraces, and wave-terraces, and delta-terraces, and others, all marked by distinct features. A lake should leave wave-terraces or delta-terraces. In revisiting Marsh Valley, he traversed it from end to end, making a careful search for the terraces of the ancient shores, selecting the most favorable stations and lights he could get. He saw stream-terraces and displacement-terraces of considerable magnitude, and a few inconspicuous terraces due to unequal erosion, but no wave-terrace and no delta-terrace. He made a special examination of two terraces referred to by Dr. Peale in support of his views, but did not recognize in them any features inconsistent with the opinion that they are stream-terraces. He consents to reconsider his original location of the outlet of the lake at the time of the beginning of the overflow, and assigns it to a position two miles north of Red Rock, instead of at that point, and the distance nearer to the place fixed by Dr. Peale than the place where he first fixed it. Mr. Gilbert Thompson, an expert topographer, visited the northern limits of the lake in 1877, while ignorant of the results of Mr. Gilbert's examination, and came to the same conclusion that he had reached. In a letter to Mr. Gilbert, dated April 10, 1878, he says: "I was delighted, at Red Rock, to see unmistakable evidences of the ancient outlet of Great Salt Lake. . . . Thus you may have the gratification of knowing of an independent and entirely unbiased verification of your determination of this point."

A Fresh-water Medusa.—A new medusa, which lives in fresh water—the first fresh-water medusa known—has been discovered in the tank of the water-lily house of the Royal Botanical Society in London. It flourishes and multiplies rapidly in water of a temperature of about 90°, and the specimens with which the tank swarms are described as being very energetic in their movements and apparently in the conditions which contribute most completely to their well-being. The new jelly-fish has attracted great attention among naturalists, and minute descriptions of it are given by Mr. Romanes and Drs. Allman and E. Ray Lankester. Mr. Romanes has found that exposure to sea-water kills it, and that it is more intolerant of sea-water than are the marine medusæ of fresh water. Dr. Allman has named it *Limnocodium Victoria* and gives it a position between the *Leptomedusæ* and the *Trachomedusæ*, while he regards its affinity with the *Leptomedusæ* as the closer.

Origin of Chinese Civilization.—A new view of Chinese civilization has been presented by M. A. Terrien de la Couperie, who asserts that the ordinary opinion, which would regard China as a world by itself—with a distinct language, and a peculiar way of writing which it has invented for itself—is incorrect, and is based on insufficient study. The error has been committed by regarding the Chinese and their language as they are, and not studying them historically and tracing them as far back as possible. This M. Terrien de la Couperie has done, according to the testimony of Professor Robert K. Douglas, with success. Great changes were made in the language in the early centuries of the Christian era, and the present system dates from no further back than the fourth century. The more ancient language may be studied from a number of sources, of which M. Terrien specifies eleven classes. One of the most important documents is the Yh King, which is supposed to embody some of the most ancient writings in the language. Some of the texts are attributed to the times of the legendary Fuhhe, B. C. 2852, and became the subject of commentaries as early as B. C. 1150. M. Terrien is the first person in modern times who has succeeded in explaining any of it. The archaic Chinese characters were derived from hieroglyphics, and the hieroglyphics were accompanied by a certain number of phonetic signs. A study of the most ancient forms and a comparison with the other sources of information have led M. Terrien to recognize in the Chinese spoken language an ancient member of the Ural-Altaic family of agglutinant languages, in which it constitutes a new, a third division

of the Amardian group, a group which also includes the Akkadian and its dialect, the Susian and Kossian languages. The vocabulary of the ancient language, as may be shown by citations of hundreds of words, connects it with the Akkadian and Susian dialects; but it has certain "very marked grammatical affinities" with the Ugro-Finnish tongues. The resemblances of the ancient Chaldean and Chinese hieroglyphics are very strong; and one point to be noticed is that, in both systems, the images are drawn full-face instead of in profile, as in Egyptian hieroglyphics. Further evidence of the connection thus suggested is given in the facts that certain parts of the Yh King are only lists of meanings that pointedly recall the Akkadian cuneiform syllabaries; that Hoang-ti, the first of the five Chinese emperors who reigned at the dawn of history, was in the ancient language Nak-kon-ti, suggesting a correspondence with the Susian god Nakhunta and King Kudur Nakhuta; and in numerous cases of at least apparent correspondence in the most ancient titles, customs, and allusions of the Chinese and the Susians. Resemblances have also been pointed out between many Western features and those of the Chinese. A part of these, M. Terrien admits, is owing to the progress of the Chinese, to communication, and later changes; but another part, he maintains, "perhaps the earliest and most important, traces its origin to the first establishment in ancient China of a part of that Akkado-Chaldean culture, to which our modern civilizations are indirectly so referable."

Curious Discovery of a Murder.—A story of a remarkable discovery of a murder comes from Bermuda. A handsome and decent mulatto woman suddenly disappeared in October, 1878, and her husband was suspected of having murdered her, but no trace of her could be found, and it seemed probable that the crime would not be detected. A week afterward, while anxiety on the subject was still at its height, some boatmen, looking out toward the sea, were struck by observing in the Long Bay Channel, the surface of which was ruffled by a slight breeze, a long streak of calm, such as a cask of oil usually diffuses around it when in the water. A connection with the disappearance of the woman was at once suggested; a search was shortly afterward made at the place for the body; the skeleton was found held down by weights, and the fragments of flesh remaining upon it were in such a condition as to show that it had not lain long in the water. Identification was established by means of portions of clothing. The man, who was a fisherman, had calculated that the fish, which were numerous in the channel, would soon destroy all means of identification of the body, but it never occurred to him that their ravages as they did so would set free the matter which was to write the traces of his crime upon the surface water. The peculiar feature of the calm seems to be a novel one, not mentioned in works on medical jurisprudence and outside the experience of doctors.

The Climate and Meteorology of Zanzibar.—Considerable interest is attached to the climate and meteorology of Zanzibar, since that island is the starting-point of most of the expeditions which proceed into the interior of East Africa. Observations taken by Dr. John Robb, of the Indian army, during the five years from 1874 to 1878, show that the average rainfall, which they give at not more than sixty-one inches, or double that of England, has very materially decreased since the time when Dr. Christie and Captain Burton made their observations; and it is suggested that the decrease may be due to the destruction of the trees over the whole island by a cyclone which swept it in 1872. The average number of rainy days is one hundred and twenty in the year. The double seasons, which are of unequal duration, are marked out by the prevailing winds, and are less exactly determined by the so-called greater and lesser rains. The rainy seasons begin when the sun crosses the zenith of Zanzibar in passing to its northern and southern declinations, March 4th and October 9th. The greater rains fall in March, April, and May, the lesser rains from the middle of October to the end of the year. The driest month is September. The mean temperature of the five years was 80·6°, the hottest months being February and March, with a mean temperature of 83·1° and 80·4° respectively, the cooler are July and August,

with mean temperatures of 77·5° and 77·7°. These figures give a variation of less than 6° in a year, and to this limited range is ascribed the debilitating nature of the climate. The mean pressure of the barometer for four years differed but a thousandth of an inch from that indicated at the equator. The coast of the mainland of Africa, Dr. Robb says, is undoubtedly prejudicial to health, and both Europeans and natives of India who pass any considerable time there suffer severely from fever of a bad remittent type, and from dysentery. All seasons are bad, but some are better than others, and travelers going into the interior are usually advised to leave the coast-region before the heavy rains begin to fall. The seeds of disease are often sown by even a short residence on the coast, and the traveler dies before he has advanced many marches into the interior. Travelers, therefore, should always make a careful and quick march across the unhealthy belt of country along the coast, and pitch their camps in the higher and drier districts beyond; and, if they have to linger on the coast, they should take care to pass their nights in the safest places they can find.

Application of Cold in Industrial Chemistry.—Heat, of temperatures above the freezing-point of water, has long been known and used as one of the most powerful agents for producing the chemical operations desired by manufacturers. Heat of temperatures below the freezing-point, or cold, as it is commonly called, has been less generally employed, and enjoys less recognition as a force capable of practical application for production. It has been lately made to aid in the manufacture of Glauber's salt at some French works with such success as to suggest that its more general application is possible in other directions. Alum and copperas were formerly made from the pyretic shales of Rheims and Picardy, but the product from these sources has been driven from the market by the competition of other alums. A new process has been devised by M. Georges Fournier, of Paris, under which the lye from the oxidized shales, containing all of the aluminum sulphate and a portion of iron sulphate after a considerable part of the copperas has been deposited, is mixed with common salt in such proportion that there shall be sodium enough to combine with all the sulphuric acid, and chlorine enough to take up all the aluminum and iron. The mixed solution is then exposed to a temperature of from 3° to 5° below the freezing-point, at which the sulphate of soda is almost insoluble. That substance is deposited in the ordinary form of Glauber's salts as a fine crystalline sediment, while the aluminum and iron remain in solution as chlorides. The "mother-liquor," or lye, is then run off, and the deposit is washed in brine cooled down to the freezing-point. After it is dried, it is fit for any purpose to which Glauber's salt is applicable. The mother-liquid which has been run off may be made into a chloride of aluminum, which is valuable for disinfecting purposes. A pure chloride of aluminum, suitable for use in dyeing, and for the destruction of the vegetable matter which is mingled with wool, may be prepared from cake-alum by a similar cold process. The results of the operation are, as before, a deposit of Glauber's salt and a solution of chloride of aluminum, but the latter substance is free from the admixture of iron. Another French inventor, by exposing the lyes of the "sal mixte" of the salt-works of the Mediterranean coast, consisting of common salt and sulphate of magnesia, to a temperature of about 11° below the freezing-point, obtains Glauber's salt in deposit with a solution of the chloride of magnesium, a substance largely used for weighting textile fabrics.

Fertility of Hybrids.—Mr. Darwin, in his "Origin of Species," has mentioned a case on the authority of Mr. Eyton, in which hybrids from the common goose and the Chinese goose were as fertile as among themselves. He has now reported in "Nature" concerning his success in raising birds from the eggs of a brother and sister from the same hatch of hybrids of these two species. Two trials were made: three birds were hatched from the first set of eggs, two others were fully formed but did not succeed in breaking through the shell, and the remaining eggs were unfertilized. From the second lot of eggs two birds were hatched. The

hybrids, grandchildren of the pure parents, were extremely fine birds, and resembled their hybrid parents in every detail. Mr. Darwin's success was not equal to that of Mr. Eyton, who reared eight hybrids from one set of eggs; and he attributes the difference in part to the close confinement in which the hybrid parents were kept and their close relationship. Another illustration of the possible fertility of hybrids to which attention has been directed, is given in Mr. J. A. Allen's "History of the American Bison," where it is said that that animal interbreeds freely with the domestic cow, and that the half-breeds are fertile.

The Highest Mountains of the Earth.—Hermann von Sclagintweit Sakünlinski, in the last volume of his journeys in India and high Asia, gives a table of altitudes, including statements of the heights of the most elevated mountains. The elevations are not extraordinary south of the Himalayas, the most marked ones being four mountains from 11,000 to 15,300 feet high in Assam, and the Sufed Koh peak in the Punjaub, 19,839 feet high. The eastern Himalayan district, embracing Bhootan, Sikkim, and Nepaul, contains the highest mountain known on the earth, which is called Mount Everest by the British, Gaurisankar by the people there, and is 29,002 feet high; and the third highest, Kintchinjunga, 28,156 feet high, and has besides thirty-two mountains of more than 20,000 feet, and thirty-two of more than 10,000 feet. The western Himalaya region, extending from Kumaon to Hazasa, exhibits the Nanda Devi in Kumaon, 25,749 feet, as its highest peak, and has besides twenty-nine mountains of more than 20,000 and 108 of more than 10,000 feet in height. In eastern Thibet are ten Alpine stations between Lassa and Guari Khorsum, more than 10,000 feet high, two of them reaching to 15,500 and 16,700 feet, and Lassa, the capital, is 11,700 feet high. Western Thibet, from Guari Khorsum to Balti, ranks next after the eastern Himalayan region in its elevations, having within its boundaries the second highest mountain known on the earth, the Dapsaug, 28,278 feet high, with twelve mountains of more than 20,000 and seventy-three of more than 10,000 feet in height. The highest point in eastern Turkistan is the summit of the Kwen-lun, 20,000 feet high. The great passes of the world are in this territory. They include the Kizilkorum pass in Yarkand, at an elevation of 17,762 feet, the Kilian pass in Khotan, 17,200 feet, and the Elchi-Davan pass in the Kwen-lun Mountains. The snow-line appears at a height of 15,100 feet on the north side of the Kwen-lun, of 15,800 feet on the south side, of 18,665 feet on the western slopes of the Guari Khorsum, and 18,010 on the northern slopes; and phanerogamous plants reach up to 19,237 feet on the western side. The highest places inhabited by man are in Thibet at a height of between 14,800 and 15,000 feet, but above these are the Hanli Cloister, 15,117 feet, and the Thok Jalang gold-field, 16,330 feet. In all, these mountain regions contain seventy-three peaks more than 20,000 feet high, of which seventeen rise above 25,000 feet. Dhawalagiri, in Nepaul, 26,680 feet high, which was formerly considered the highest mountain on the earth, is remanded to the fifth place, being exceeded, besides the three already named as the three highest, by the Sisbut peak, in Nepaul, 27,799 feet.

Butter-making in Denmark and Sweden.—Some of the best butter in Europe is made in Denmark and Sweden, and commands a price in the London market 23 per cent. higher than the best Cork butter. Canon Bagot, who has taken pains to investigate this subject, ascribes this superiority to the education of the dairy-maids, which has been systematically pursued in Denmark since 1864 and 1865. In Sweden the dairy-maids are sent to a college and educated in dairy management for six months, at the end of which time they receive certificates and are considered competent to work in large dairies. Their instructions are very definite as to every feature of the operation of butter-making, including the quality of the salt and the coloring matter, and the food of the cattle; the quality of the butter is consequently uniform. A part of a lot of Cork butter may sometimes be sent back by the wholesale dealer because it is not equal to the rest, but this is said never to happen with Danish butter. The selection of the cows and the feeding of them are the first important points in the business. The Dan-

ish dairymen keep their cows tethered during the summer in "splendid clover and rye grass," and feed them in winter exclusively with clover hay, linseed-cake, and rapé-cake. The milk is set in such a way that the cream shall be got off while it is still perfectly sweet, for they will not churn it if it is in any other condition. The proper temperature for churning, which is from 57° to 60°, is essential, and the churning should not be continued too long. The best butter-makers stop churning at the very moment the butter appears in the form of grains like shot. They pass off the buttermilk through a strainer, then put the butter back with water, give it a few more turns in the churn, strain again, and repeat the operation till the water runs off as clear and bright as when it is put in. Salt is added by weight, at the rate of six pounds of salt to a hundred-weight of butter, by being sprinkled over the butter after it has been spread out in layers; a few turns are given the mass with the butter-worker, and the process is complete.

Diffusion of Bacteria.—M. Miguel has learned from his investigations of bacteria and germs in the atmosphere that the number of bacteria, which is small in the winter, increases through the spring, and becomes large in the summer and fall, then diminishes again during the months of frost. The same is the case with the spores of fungi; but while the molds are abundant during moist periods, the number of aërial bacteria then becomes very small, and does not increase again till the soil has been dried, precisely when the fungoid spores are rare; so that the maxima of mold-microbes and the minima of bacteria-microbes correspond with each other, and *vice versa*. While in the summer and fall a thousand germs of bacteria may often be found in a cubic metre of air, in winter the number falls to four or five, and on some days the dust from two hundred litres of air is incapable of causing the infection of the most alterable liquors. Usually, in M. Miguel's laboratory, the dust of five litres is enough to cause infection, and in the sewers of Paris the particles in one litre will do it. A comparison of the number of deaths in Paris from infectious diseases with the number of bacteria present in the atmosphere showed that every increase of bacteria in the air was followed in about eight days by an increase of the deaths in question. M. Miguel further represents that he has found that the water-vapor which rises from the ground, from rivers, and from masses in full putrefaction, is always micrographically pure, that gases from buried matter in the course of decomposition are always exempt from bacteria, and that even impure air sent through putrefied meat is purified under certain conditions.

The Thread-Worm of the Dog.—The cruel thread-worm (*Filaria immitis*) of the dog was described thirty years ago in the "Proceedings" of the Academy of Natural Sciences of Philadelphia, and has since been repeatedly noticed as infecting dogs in Europe, India, China, Japan, and this country. The heart of a dog, with the ventricles stuffed with the worms, is preserved in the Museum of the University of Pennsylvania. A specimen of the heart and part of one lung of a dog containing the worms has recently been sent to the Academy of Natural Sciences, by Mrs. Laura M. Towne, of Beaufort, South Carolina, who has also furnished a description of the symptoms shown by dogs afflicted with the parasite. She had lost several dogs, and a gentleman living on a neighboring island had lost more than thirty hunting-dogs in two or three years with the same symptoms. The most characteristic symptom appears to be a peculiar cough, which is excited by any movement, especially after sleeping, ending in a violent effort to bring something from the throat, but nothing is thrown up. When they began to run violently, the afflicted dogs would fall down and become stiff and insensible, but would in a short time get up and renew the chase. A large Newfoundland dog grew ill, exhibiting the drowsiness, lassitude, and inclination to turn round and round when he attempted to go anywhere, which marks the conduct of sick dogs, and finally became subject to spasms. He was examined after death, when one *filaria* was found lying at full length in the windpipe, and others were found stretched at length and crowded closely in the large artery. Upon cutting into the heart, the worms

burst forth in bunches, slowly uncoiling themselves. They were white, stiff, and wire-like, and not at all stained with blood. The large blood-vessels of the lungs were filled densely, and large *filariæ* were withdrawn with some difficulty even from the small ones. The worms lived in water about twenty-four hours.

Production of Artificial Diamonds.—Mr. Hannay lately gave an account to the Royal Society of his experiments in producing artificial diamonds. As far back as the fall of 1879, he was searching for a solvent of the alkali metals, and tried many experiments with different liquids and gases, with the invariable result that, when the solvent reached the permanently gaseous state, chemical action ensued. A number of experiments were made with sodium, potassium, and lithium, and the hydrocarbons, but the metals almost invariably combined with the hydrogen, setting the carbon free. A series of experiments made with sodium and paraffine-spirit gave a deposit of very hard scales of carbon. This was the reaction upon which the experiments for obtaining crystalline carbon were built. From his experiments in solution, Mr. Hannay concluded that the solvent power of water was determined by two conditions: first, temperature, or molecular *vis viva;* and, second, closeness of the molecules on pressure, which seems to give penetrative power. It should follow, then, that, if one body has a solvent action upon another without acting upon it chemically, such solvent action may be indefinitely increased by increasing the temperature and pressure of the solvent. Out of more than eighty experiments which Mr. Hannay made for producing crystallized carbon, only three were attended by results of a satisfactory nature. The first experiments were made with sodium and paraffine-spirit, in tubes of hydraulic iron, twenty inches long, an inch thick, and of a half-inch bore, three parts filled. The tubes, fitted with screwed plugs, nearly all leaked, and had to be welded up. Then one exploded before it became visibly red, another showed a deposit of scaly carbon, and a third gave out a strong jet of gas when opened, while the iron appeared to have been converted to steel. Concluding that diamonds were not likely to be obtained by that means, Mr. Hannay returned to the idea of dissolving carbon in a gaseous menstruum. A distillation from bone-oil containing nitrogenous bases seemed to him the most likely substance to yield the solvent. It was placed in a strong tube with charcoal, and heated for fourteen hours. The gas rushed out with force on opening the tube, and a few bright particles of carbon appeared, differing but little, however, from particles of wood-charcoal. Another experiment was made with lithium and a mixture of highly rectified bone-oil and paraffine-spirit, placed in a tube twenty inches by four inches, with a bore of half an inch. This was heated for fourteen hours, then cooled slowly. On opening it, after the outrush of gas a little liquid was found, and at the upper end of the tube as it lay in the furnace, a hard, smooth mass, which was removed with a chisel. Some hard particles were found in pulverizing this mass, which, on examination, proved to be transparent crystals of carbon, or diamonds. New experiments were made with other alkali metals, paraffine-spirit, and bone-oil, but they yielded nothing except the scaly carbon. Even the lithium did not act in the same manner as before. This metal having, however, given the best results, Mr. Hannay determined to use it in his further experiments, but was troubled by frequent disasters and explosions, although he again got, in one of the trials, a small quantity of carbon crystals. A curious fact that has been brought out by the examination of the crystallized carbon that was obtained is that nitrogen was present in chemical combination with the carbon. Mr. Hannay is inclined, therefore, to believe that his diamonds were formed by the decomposition of a nitrogenous body, and not by the decomposition of the hydrocarbon. The diamonds, moreover, were not found when nitrogen was absent; but the successful experiments are still too few, and the evidence too vague, to justify drawing any conclusions on this subject.

The Nile and its Ancient Channels.—M. Delamotte, who has made himself well acquainted with the geology and geography of Egypt, has published the opinion that, besides the Nile, that country was watered

in prehistoric times by rivers that ran through the present dry sand-channels which the Arabs call Bahr-et-Abied, or rivers without water. The fact that river-shells were discovered in these beds during the French expedition to Egypt lends some support to this view. M. Delamotte has devoted some twenty years to the examination of the subject, and, while he does not undertake to determine when the rivers were dried up, he has reached a conclusion as to the manner in which it was done. He believes that the whole plateau of Khartoum was in prehistoric times a grand lake whence the Nile issued as it now issues from the Victoria and Albert Nyanzas. The cataracts were, however, higher than they are now, and the river, instead of precipitating the whole mass of its waters over the rocks, was divided into streams which found their way through the channels marked by the present Bahr-et-Abiad, and carried the water into the parts of the country which are now desert. The granite and porphyry of the cataract were gradually worn away in the course of ages, their level was lowered, and the Nile, instead of being forced into branch-channels, fell over them and concentrated its waters into its present single stream. M. Delamotte is examining the region of the Upper Nile again, for the purpose of verifying his theory, and of determining if it is possible, by constructing a system of dams and sluices, to raise the level of the cataracts, and cause the waters to flow again through the channels they have deserted.

Sports in the Colors of Squirrels.—A correspondent of "Forest and Stream" relates an interesting instance of the development of varieties of colors in squirrels, which took place in South Carolina several years ago. A Mr. K——, who owned a considerable plantation in the county of Marlborough, had presented to him a pair of milk-white squirrels. His woods were much frequented by gray squirrels, and fox and black squirrels were numerous in the pines and cypress-swamps at some distance from the plantation. The white squirrels bred, producing two young ones, also milk white. The animals were very prolific, under the protection of the owner, who prohibited the intrusion of hunters, and, in course of time, spread to the adjoining plantations, and many of them took to the immense swamps bordering on the Big Peedee River. They also began to sport and change their color, and, from being pure white, became marked with every possible variation of black and white. The correspondent who relates these facts has killed, at various times, at least a dozen thus marked. One of them was of a deep, sparkling black color, except as to the ears and the large, bushy tail, which were snow-white, save a small commingling of the black and white at the root of the tail, and the lower part of the belly and the inner edge of the flanks, which were of a clear ash-gray. The varieties seem to have almost disappeared since the war. In the last individual that the correspondent has noticed, the markings were less pretty and the colors less distinct; the white was turning to ash and the black to brown, the consequence, he supposes, of wild breeding.

A New African Tribe.—Dr. Emil Halub recently addressed the London Geographical Society respecting a hitherto undescribed African tribe called the Marutse. They inhabit the country formerly ruled by the Makololo, described by Dr. Livingstone, who have ceased to exist. Dr. Halub said that when he crossed the Zambesi, and entered into their country, it seemed that he had left Africa, for the tribes were entirely different from the others in South Africa. They belong to the Banti family, but differ from the other members of this family in their appearance, customs, and workmanship. They have their own civilization, independent of influence from white men; and, while the other tribes have nothing which could be called a religion, they believe in a Supreme Being and in a life after death. They call the Supreme Being N'yambe, but have so great a reverence for him that they do not like to pronounce his name. Whenever a serious event happens, as when a man is killed by a buffalo, a crocodile, or an elephant, the common expression is "N'yambe has ordered it, and it is no use resisting." When a member of the royal family was ill, he was taken to the grave of one of his ancestors, when the king knelt on the grave, and prayed to the deceased, "You, my

grandfather, who are near to N'yambe, pray to N'yambe that the disease may be taken from this man." When a great disaster happened, as in the case of the river overflowing its banks, the people gathered around the graves of the chiefs, and prayed, "You, who are with N'yambi, pray for us." Previous to the present reign, the king was assisted by a Great Council and a Privy Council, and the cases of persons who were thought to be guilty of crimes deserving capital punishment were submitted to the Great Council for decision. The present king has abolished this usage. This king assumed to have supernatural powers, and the people believed in his pretensions and were afraid of him; but he attempted at one time to exercise his powers publicly to secure the return of some chiefs whom he had condemned to death and who had run away, and failing, lost his reputation. The people are superior to all the South African tribes in the character of their clothing, their skill in working in ivory and metals, and their customs generally. They trade with the other tribes to the north and to the west. They excel the more southern tribes in mental ability, cultivate music, and hold women in high esteem.

Hygienic Conditions of School-Life.—The "Lancet" has undertaken to inquire into the hygienic conditions of school-life in educational establishments, including those in which only the most limited numbers of pupils are taken. Aiming principally to disclose defects which are generally overlooked or little noticed, it invites and expects the coöperation of the conductors of the schools. It has framed a list of questions relating to the character and capacity of the premises, their original purposes and their adaptation to the uses of a school, the accommodations for pupils, provision of air and diet, the hours of school work and the time given wholly to play, the general health of the establishment, and the amount of illness during the year, the appearance or non-appearance of epidemic disease, the sanitary arrangements proper of the establishment, the provisions for isolation in case of a sudden attack of infectious disease, and the system of medical inspection which may be in use. The results of its inquiries as a whole will be given in the form of reports and suggestions with a view of defining, so far as may seem expedient, the conditions of health in body and mind of youth attending school.

NOTES.

Mr. R. E. Earle, of the United States Fish Commission, observed this year that the Spanish mackerel (*Cybium maculatum*) was spawning freely in Chesapeake Bay. He reported his discovery to Professor Baird, and then proceeded to hatch out the spawn with most satisfactory results, getting about half a million of fish in three or four different lots. The fry, which were hatched in water of 84° in eighteen hours after impregnation, seem to be unusually hardy. Preparations will be made to hatch out immense quantities of fish during the next spawning season. The fact is established by these experiments that this fish is quite able to live in brackish water.

Professor E. B. Andrews died at Lancaster, Ohio, on the 21st of August, in his sixtieth year. He was a graduate of Marietta College, in which institution he was Professor of Geology from 1861 until 1869, when he joined the Geological Survey of the State. He is the author of some of the most valuable reports of the survey, and to him is due a careful study of the coal deposits of the southeastern section of the State, and of other of its mineralogical and geological resources.

It was noticed several years ago that, when white light was mixed by the method of rotating disks with ultramarine, the color instead of assuming a paler tint of violet-blue became more violet, and passed, when much white was added, into a pale violet. Professor Rood, of Columbia College, has been trying the results of mixing white with other colors, and has found that, instead of giving lighter shades of the original color, the effects are such as would be produced by adding a quantity of violet light. Thus, vermilion becomes somewhat purplish, orange more red, yellow more orange, yellowish-green more green, green more blue-green, cyan-green less greenish, more bluish, cobalt-blue more of a violet-blue, ultramarine (artificial) more violet, purple less red, more violet. Only greenish-yellow is not changed.

The Society of American Taxidermists, recently organized at Rochester, New York, is believed to be the first of its kind ever established. Its avowed object is to combine the skill and knowledge of taxidermists in the development of their art, and to raise it

to a level with the kindred fine arts of painting and sculpture. The first general meeting and exhibition of the Society will be held in Rochester about December 20th, when displays are invited of stuffed animals in groups, single specimens, etc.

BRIGADIER-GENERAL ALBERT J. MEYER died at Buffalo, the 24th of August, in the fifty-third year of his age. He early turned his attention to the devising of practicable methods of signaling, and rendered efficient service by this means during the war. He was chiefly known to the public by his work in connection with the establishment and development of the present extensive and complete Weather Service, of which he was the chief officer.

A FRENCH chemist, M. Alland, has found a way to give a solid and soluble form to sulphuret of carbon, by which it is made much less volatile, more convenient to handle, and more efficacious as an insecticide. He dissolves the sulphuret in a heavy oil which is formed in the manufacture of anthracene and saponifies with lime, and adds quicklime to the solution. The paste thus obtained is soaked in water and dried into a cement which forms an isolating crust. A very effective insecticide, which, however, acts slowly, is thus obtained.

PROFESSOR C. W. BORCHARDT, of the University of Berlin, died at Rüdersdorf, near Berlin, June 27th. He was formerly Professor of Mathematics in the Prussian Military Academy, and had been since 1856 editor of the "Journal for Pure and Applied Mathematics," the oldest of the existing mathematical periodicals.

THE President of the Anthropological Institute of London has attempted an explanation of the long-standing and puzzling question of the manner in which the huge and heavy stones which stand as monoliths or in groups as tombs or temples were lifted into their places. Some of the hill tribes of India still erect big stones as memorials, and it is reported of one of them that they recently carried a stone weighing twenty tons up a high hill in the course of a few hours. The ponderous block was inclosed in a wooden framework so arranged that a large number of men could lift all at once, and in this simple way it was borne to the hill-top, a height of four thousand feet.

THE London "Times" has tried with success the experiment of having reports of the debates of the House of Commons transmitted by telephone directly to its compositors while they are at work. The notes made by the reporter are read directly into the telephone-receiver in the room adjoining the gallery of the House, and are received by the compositor who sits with his ears near the office terminus of the instrument. The compositor is provided with a system of signals by means of which he can control the rate at which the reports are transmitted to him, and have all the corrections and explanations he may need made on the spot.

M. CHARPENTIER has measured the variation in the intensity of light to which the eye is sensitive, and has found it to be equivalent to about seven or eight hundredths; that is, a given light, whether strong or weak, must be diminished or increased in that degree to give a new sensation distinct from the former one. The difference is essentially the same in direct and indirect vision and with light of every color.

THE death is announced of M. Lissajous, Professor of Physics at Toulouse, and author of several valuable scientific memoirs.

ACCORDING to a recent report of the Boston Board of Health, appreciation of the necessity of good sanitary conditions is steadily increasing in that city. Requests for the inspection of premises are now frequent, while a few years ago obstacles were thrown in the way of inspectors by the landlords. This regard for proper sanitary construction is not confined to any class, but is exhibited alike by the owners of elegant mansions and of the most ordinary dwellings.

MR. A. A. BRENEMAN has obtained some very satisfactory results in the color decoration of common gray stone-ware. The process was described in a communication to, and samples of the ware exhibited before, the Chemical Section of the American Association at the recent Boston meeting. This sort of ware has hitherto been decorated only in blue, but these samples showed that a wide range of coloring was possible. The process is simple and comparatively inexpensive.

LOUIS FRANÇOIS DE POURTALES died at Beverly Farms, Massachusetts, on the 17th of July, in his fifty-seventh year. Since the death of Professor Louis Agassiz, he has been the keeper of the Museum of Comparative Zoölogy at Harvard, and was well known among scientific men for his work in connection with deep-sea dredging.

A STATEMENT by Professor Mivart in a recent paper on tails, respecting the non-existence of monkeys in the West Indies, has been shown by correspondents of "Nature" to be an error. Monkeys are found in the islands of St. Christopher and Nevis, and in Grenada, where they exist in large numbers in the wild state, and are very destructive to the growing crops. Apes are also said to be found wild in Montserrat.

INDEX.

PAGE

Adipose, The Impediment of..... 60
Affection, Animal..... 406
Africa, Prehistoric..... 287
African Tribe, A New..... 862
Albro, W. P., Letter from..... 121
Algæ, Relation of, to the Phanerogams..... 714
Algebras, Spaces, Logics..... 516
Algerian Sahara, Fertilization of the..... 138
Allen, Professor Grant..... 495, 650
Amherst College and Evolution..... 120
Amherst College, Evolution in..... 405
Anæsthetic, A New..... 424
Ancient Race, Relics of, in Eastern New York..... 286
Animal Development, The Rate of..... 254
Animals, and the Faculty of Direction..... 692
Animals, Legal Prosecutions of..... 619
Anthony, Professor W. A..... 831
Ant, The Cutting..... 717
Ants, Slave-making..... 424
Artesian Wells on our Western Plains..... 428
Asphalt and Amber in the Mud of New Jersey..... 718
Association, American Scientific..... 693
Automatism in Portrait-Painting..... 140

Bacteria, Diffusion of..... 860
Barker, George F., Modern Aspects of the Life-Question..... 750
Barnard, W. S., Zoölogical Education..... 666
Bee, Lessons from the Tongue of the..... 422
Bell, Alexander Graham..... 813
Beer, About..... 280
Bellesme, M. J. de, How Insects direct their Flight..... 114
Berghaus, Dr. A., The Medicinal Leech..... 478
Birds, Æsthetic Feeling in..... 650
Birds, Notes on a Few of our..... 386
Blake, E. Vale, The Impediment of Adipose..... 60
Bolas, Thomas..... 802
Bookbinding, Deterioration of, by Illuminating Gas..... 143
Books noticed:
"England: Her People, Polity, and Pursuits" (Escott)..... 126
"The Interoceanic Canal and the Monroe Doctrine"..... 127

Books noticed: PAGE

"Free Ships" (Codman) ... 127
"Labor-Making Machinery" (Powers) ... 127
"Action of the United States Tariff" (Tylor) ... 127
"Report of the Department of Public Works of the City of New York" ... 129
"The Theosophist" ... 130
"Report of Harvard College Observatory" ... 131
"History of the English Language" (Lounsbury) ... 131
"The Mound-Builders" (McLean) ... 131
"Insect Lives" (Ballard) ... 131
"Eyesight" (Carter) ... 132
"Perception of Space and Matter" (Walter) ... 132
"The Metaphysics of the School" (Harper) ... 132
"Vocal Physiology and Hygiene" (Holmes) ... 133
"Electric Induction" (Gordon) ... 133
"Therapeutics and Materia Medica" (Semple) ... 133
"Forensic Medicine and Toxicology" (Hemming) ... 133
"Aids to Anatomy" (Brown) ... 133
"Report of the New York Meteorological Observatory for 1878" (Draper) ... 133
"Water-Color Painting" (Penley) ... 134
"Protection of Forests a Necessity" (Dorien) ... 134
"Experiments on Rainfall" (Stockbridge) ... 134
"Improved Dwellings for the Laboring Classes" ... 134
"Report on Magnetic Determinations in Missouri in 1879" (Nipher) ... 134
"Chemical Exercises in Qualitative Analysis" (Rains) ... 272
"Henry's Contribution to the Electro-Magnetic Telegraph" (Taylor) ... 272
"History of Political Economy in Europe" (Blanqui) ... 273
"Nervous Exhaustion" (Beard) ... 275
"Science Primers: Introductory" (Huxley) ... 275
"Health and Health Resorts" (Wilson) ... 276
"Instruction in the Mechanic Arts" (Atkinson) ... 276
"The Cotton-Worm" (Riley) ... 276
"Index to the Publications of the United States Naval Observatory" (Holden) ... 276
"Report on Lands of Arid Region of the United States" (Powell) ... 276
"Studies in Fermentation" (Pasteur) ... 277
"Text-book of Physiology" (Foster) ... 277
"A Forbidden Land" (Oppert) ... 277
"Geological Survey of Colorado" (Hayden) ... 278
"Sunshine and Storm in the East" (Brassey) ... 278
"Preadamites" (Winchell) ... 410
"Life and Writings of Buckle" (Huth) ... 412
"Fundamental Concepts of Modern Thought" (Eucken) ... 413
"Chemistry" (Bloxam) ... 413
"Pharmacographia" (Flückiger) ... 414
"Philosophy of Religion" (Caird) ... 414
"Watering-Places of Germany, Austria, and Switzerland" (Gutmann) 415
"Life: Its True Genesis" (Wright) ... 415
"Handbook of Hygeine and Sanitary Science" (Wilson) ... 416
"Handbook of Double Stars" (Crossley, Gledhill, and Wilson) ... 416

Books noticed: PAGE
"Pay Hospitals" (Burdett) 416
"Key to Ghostism" (Mitchell) 417
"Common Mind-Troubles" (Mortimer-Granville) 417
"Sanitary Dwelling-Houses" (Corfield) 417
"Our Homes" (Hartshorne) 417
"Education" (Spencer) 560
"New Departure in Collegiate Control and Culture" (Mills) 563
"The Morals of Evolution" (Savage) 564
"Brain and Mind" (Drayton) 564
"Sea-Sickness" (Beard) 564
"The Throat and its Functions" (Elsberg) 565
"Alva Vine" (Gordon) 565
"Study of Some of the Starches" (Stowell) 565
"Management of Children" (Hale) 565
"Prevention of Disease" (Weist) 565
"Problems of Insanity" (Beard) 565
"New Characters of Mosasauroid Reptiles" (Marsh) 566
"Bulletins of the United States Survey of the Territories" 566
"Guide to Modern English History" (Cory) 566
"Introduction to Study of Sign-Languages among North American Indians" (Mallery) 566
"Camps and Tramps in the Adirondacks" (Northrup) 566
"Report of Wisconsin Geological Survey for 1879" (Chamberlin) 567
"Deutsch-Amerikanische Apotheker-Zeitung" 567
"Silver in Relation to Industry and Trade" (Brown) 567
"Naturhistorische Verein für Wisconsin 567
"Early Man in Britain" (Dawkins) 697
"Reports of the Peabody Museum of American Archæology and Ethnology" 698
"Taxidermist's Manual" (Brown) 699
"Fugitive Spectra" (Trouvelot) 700
"Proceedings of Davenport Academy of Natural Sciences" 700
"Health and Healthy Homes" (Wilson) 701
"Water Analysis" (Frankland) 701
"Health" (Corfield) 702
"Child's Catechism of Common Things" (Champlin) 702
"Free Land and Free Ships" (Cox) 702
"Sea-Air and Sea-Bathing" (Packard) 702
"Radical Mechanics of Animal Locomotion" (Wainwright) 702
"The Microscope in Medicine" (Beale) 703
"The Field Engineer" (Shunk) 703
"Hygienic and Therapeutic Relations of House-Plants" (Anders) 703
"Fabulous Gods denounced in the Bible" (Hauser) 703
"Practical Keramics" (Janvier) 704
"Tin in Burmah, Siam, and Malacca" (Reyer) 704
"Schiller's Complete Works" (Hempel) 704
"Landsberg's Illustrated Weekly" 704
"Tromsö Museums Aarshefter" 704
"The Brain as an Organ of Mind" (Bastian) 846
"Degeneration" (Lankester) 848
"The Obelisk and Freemasonry" (Weisse) 849

Books noticed: PAGE
"Surveys of Northwestern Lakes" (Comstock) ... 849
"The Microscopist's Annual" ... 850
"North American Entomologist" ... 850
"Haveenoid" (Mott) ... 850
"The Oriental and Biblical Journal" ... 850
"The Thousand Islands" (Hough) ... 850
"Coal-Trade of Pennsylvania" (Sheafer) ... 851
"American Health Primers" ... 851
"Memoirs of the Science Department of Tokio University" ... 851
"American Journal of Philology" ... 851
"Report of the Department of Statistics and Geology of Indiana" ... 852
Boole, George, Sketch of. (Portrait.) ... 840
Botel Tobago, The Aborigines of ... 718
Breath, Temperature of the ... 855
Buchan, J. M., Climate and Complexion ... 1, 279
Buffalo, The, and his Fate ... 40
Butter-making in Denmark and Sweden ... 859

Criminal Law, Origin of ... 121
Carbon Button, The. (Illustrated.) ... 10
Carlisle, the Lord Bishop of, God and Nature ... 27
Carpenters, About ... 233
Carpet-Beetle, The ... 287
Catskill Mountains, The ... 568
"Ceremonial Institutions," The London "Times" on ... 125
Chemical Exercises for Ordinary Schools ... 522
Chemistry, Industrial Application of Cold in ... 858
Chemistry, The New, a Development of the Old ... 393
Child, A. L., Letter from ... 692
Children, New-born, Hygiene of ... 715
Children, The Infectious and Contagious Diseases of ... 249
Chimborazo and its Climbers ... 714
Chinese Civilization, Origin of ... 856
Cinchona-Forests, The, of South America ... 507
Circulation, Changes in the, during Cerebral Activity ... 303
Clarke, Professor F. W., My Fire ... 321
Classics, The, that educate us ... 145
Climate and Character, American ... 705
Climate and Complexion ... 1, 279
Crayfish for Study ... 405
Crayfish, The, Where to find ... 135
Coloring of the Waters in Seas and Lakes ... 706
Comets of 1843 and 1880, The ... 714
Coöperation in England ... 742
Copyright, International, Wilkie Collins on ... 554
Copyright, Matthew Arnold on ... 121
Cotton-Worm, Investigation of the ... 795
Criticisms corrected ... 692
Correction, A ... 120, 405, 552, 692
Correspondence ... 823
Cumings, Elizabeth ...

PAGE
Currents, Atmospheric, and Carbonic Acid 421

Daly, Chief Justice, Recent Geographical Exploration 171
Dampness and Diphtheria 281
Damposcope, The 282
Darwin, Francis, Climbing Plants 635
Deformity, Fashion in. (Illustrated.) 721
Delpech, Dr., the Infectious and Contagious Diseases of Children 249
Desert, Central Arabian, Features of the 281
Diamonds, Artificial 259
Diamonds, Artificial, Production of 861
Disease, Water in 854
Distribution of Plants, On the Modes of 365
Diving-Process, Mr. Fleuss's New 575
Dogs, Domestic, Origin of 420
Dog, Thread-Worm of the 860
Dress, in Relation to Health 182
Dust, A Shower of 553
Dust, Atmospheric 344

Earth, The Interior of the 289, 453
Earthquakes, A Systematic Investigation of 429
Echoes in Buildings 141
Editor's Table 121, 265, 406, 554, 693, 843
Education as an Aid to the Health to Women 823
Electrical Experiment, An, of the Eighteenth Century 422
Electric Light, The, and Vegetation 283
Electric Light, The Jablochkoff, in London 706
Electricity and Agriculture 664
England, Coöperation in 742
Engler, E. A., the Carbon Button 10
Energy, The Availability of 244
Enigma, A Zoölogical 359
Epidemics 425
Equatorial Temperatures 715
Ethics, Scientific, A Vindication of 324
Europe, The Winter in 136
"Evolution admitted, what then?" 409
Explanation, An 582
Exploration, Recent Geographical 171
Explosion, A Remarkable Coal-Mine 429
Eyesight of Readers, The 711

Fairchild, Herman L. 224, 600
Farbenlehre, Goëthe's 215, 312
Fashion in Deformity 721
Feet of Chinese Women, Compression of 712
Ferment, A Fossil 138
Fetich-Worship and Witchcraft, African 428
Fison, Lorimer, Views of Primitive Marriage 203
Flower, William Henry, Fashion in Deformity 721

PAGE
Forests, Silicified, of the Yellowstone Park 570
Fossil Man, The 350

Glass, to pierce, with the Electric Spark 285
Geology and History 495
Geology, Studies in Experimental 200
George, Henry, the Kearney Agitation in California 433
Germs, Destruction of Infectious 824
Goatman, E. A., Letter from 405
Goethe and the Artistic Study of Nature 406
God and Nature 27
Green, Traill, Letter from 552
Griffin, La Roy F., Animals and the Faculty of Direction 692

Halstead, George B., Algebras, Spaces, Logics 516
Harvard Medical Course, The 716
Harvard, Recent Original Work at 482
Haynes, Henry W., the Fossil Man 350
Health-Cure, The, as a Remedy for Adversity 574
Heat-Engines, Possible Efficiency of 831
Heliograph, Messages by 716
Herbert, Hon. Auberon, State Education: a Help or Hindrance? 585
Hicks, J. D., Letter from 552
Higgs, Dr. Paget, Electricity and Agriculture 664
Hitchcock, J. R. W., Recent Original Work at Harvard 482
Hoffmann, Frederick, Sketch of Friedrich Mohr 402
Horses, Managing, by Electricity 139
How Animals digest. (Illustrated.) 600
How Animals eat 224
Human Race, The Crossing of the 166
Huxley, Professor T. H. 337, 467
Hybrids, Fertility of 858
Hygieopolis, A Chinese 287
Hysteria and Demonism 86, 155, 376

Iceland 710
Iles, George, Coöperation in England 742
Illusions and Apparitions 571
India-Rubber Industries 802
Ingersoll, Ernest, the Buffalo and his Fate 40
Intelligence, Animal 287
Insects, Bacteria as Destroyers of 93
Insects, How they direct their Flight 114
Insects in Libraries 286
Insect-Powders as Remedies for Flies and the Aphis 282
Ivins, William M., Comparative Jurisprudence 577

James, Joseph F., on the Modes of Distribution of Plants 365
Japanese, Stature of the 142
Jones, William, Legal Prosecutions of Animals 619
Joy, Professor Charles A., Biographical Sketch of Frederick Wöhler 539
Jurisprudence, Comparative 577

PAGE
Kearney Agitation, The, in California 433
Kirkwood, Daniel, Letter from 553

Lake Bonneville, Ancient Outlet of 855
Lankester, E. Ray, F. R. S., Bacteria as Destroyers of Insects 93
Law of Mutual Help, The 709
Lee, Professor William, M. D., the Extreme Rarity of Premature Burials .. 526
Leech, The Medicinal 478
Leidy, Joseph, Sketch of. (With Portrait.) 684
Le Sueur, M. D., a Vindication of Scientific Ethics 324
Life-Question, Modern Aspects of the 750
Light, Production of Sound by 813
Lightning-Conductors, Efficiency of 421
Lights, Rhythmic and Colored, for Lighthouses 427
Literary Notices 126, 272, 410, 560, 697, 846
Literature, Sham Admiration in 48
Lord, W. W., Letter from 120

Man in America 571
Marsh-Odors, The Source of 138
Mauris, Maurice, About Carpenters 233
Maxwell, James Clerk, Sketch of 116
Meat, Diseased, Effects of 572
Medusa, A Fresh-Water 856
Meridian, Carrying a French, into Africa 575
Merrill, Harry 386, 692
Metallic Compound, A New 282
Metals, Precious, Production of, in Colorado 287
Meunier, Stanislas, Studies in Experimental Geology. (Illustrated.) 200
Miller, W. D., the Availability of Energy 244
Minot, C. S., Changes of the Circulation during Cerebral Activity 303
Mohr, Friedrich, Sketch of 402
Mollusks, The, Capture among 111
Morphia, Danger of the Hypodermic Use of 425
Mountains, The Highest, of the Earth 859
Muir, M. M. Pattison, the New Chemistry a Development of the Old 393
Murder, Curious Discovery of a 857
My Fire (Poem) 321

Natural Vegetation at San Francisco, Changes in 853
Nature, Mysterious Sounds of 772
Newcomb, Professor Simon, Sketch of Otto Wilhelm Struve 263
Newton, The English Precursors of 669, 777
Night-Schools in New York and Paris 681
Nile, Ancient Channels of the 861
Nolan, Edward J. 684
Notes 143, 288, 431, 576, 719, 863
Nubian Race, Types of the. (Illustrated.) 512

Olfactory Nerves, Abnormal Action of 692
Origin of Species, The Coming of Age of the 337

PAGE
Ornithorhynchus, The Australian 769
Oswald, Felix L., a Zoölogical Enigma 359
Osteophone, The 142

Paint, Luminous 707
Payn, James, Sham Admiration in Literature 48
Photophone, The New 898
Plants, Climbing. (Illustrated.) 635
Politics against Political Science 557
Polyscope, The Electrical 110
Popular Miscellany 135, 279, 419, 568, 705, 853
Precocity a Sign of Inferiority 430
Premature Burials, The Extreme Rarity of 526
Preyer, W., Psychogenesis in the Human Infant 625
Primitive Marriage, Views of 203
Psychogenesis in the Human Infant 625
Publications Received 134, 278, 418, 567, 704, 852

Quatrefages, A. De, the Crossing of the Human Races 166

Radau, R., The Interior of the Earth 289, 453
Radiation, Freezing of a Lake by 572
Railway, An Electrical 285
Richardson, Dr. Benjamin W., Dress in Relation to Health 182
Richet, Charles, Hysteria and Demonism 86, 155, 376
Rhine, Alice H., Night-Schools in New York and Paris 681
Root-Growth, A Singular 427

Sanitary Problems, The, of New York City 419
Santorin and its Eruptions (M. Fouqué's) 534
Saurians, Development of the Limbs of 284
School-Life, Hygienic Conditions of 863
Science not atheistic 124
Science Primers, Misuse of the 269
Science, The Martyrdom of 71
Scientific Meeting, The Boston 843
Sea, The Milky 573
Sewage in College Education 693
Shipman, Paul R., The Classics that educate us 145
Silkworms, Rearing, in England 280
Slater, J. W 71, 254
Snakes and Snake-Poison 284
Sociology and Theology at Yale College 265
Soils as Filters 572
Solar System and its Neighbors, The 612
South America rising or sinking? 708
Sparrow, Observation of the English 552
Spencer, Herbert 795
Springer, Robert 772
Squirrels, Sports in the Colors of 862
State Education: a Help or Hindrance? 585

PAGE

St. Gothard Tunnel, The 530
Struve, Otto Wilhelm, Sketch of. (With Portrait.) 263
Suicide, A Consideration of 120
Sully, James, the Pleasure of Visual Form 77
Summer Schools of Natural History 279

Tea and Coffee, Physiological Effects of 853
Temperatures in the Pacific and Atlantic Oceans 716
Thompson, Daniel G., Letters from 120, 405
Tissandier, Gaston, Atmospheric Dust 344
Tyndall, Professor John, F. R. S., Goethe's Farbenlehre 215, 312

Violin, The, its Construction and Perfection 423
Visual Form, Pleasure of 77
Vivisection, What it has done for Man 711
Vocal Cords, Stammering of the 141
Volcano rising from a Lake 713
Volcanic Eruptions and Earthquakes in 1879 713

Warring, C. B., the Solar System and its Neighbors 612
Watches, A Test for 283
Water, Germs of Disease in 570
Watering-Places, Sanitary Perils at 426
Wellcome, H. S., the Cinchona-Forests of South America 507
Wernich, Dr. A 828
Wild Silks 137
Wilson, Dr. Andrew, Some Facts and Fictions of Zoölogy 96
Wöhler, Frederick, Biographical Sketch of 539

Youmans, Eliza A., Chemical Exercises for Ordinary Schools 522

Zadig, On the Method of 467
Zanzibar, Climate and Meteorology of 857
Zoölogical Education 666
Zoölogy, Some Facts and Fictions of 96

END OF VOL. XVII.